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ENGINEERING CONSTRUCTION BY THE UNITED STATES RECLAMATION SERVICE.

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[*Read January 10, 1906.*]

There is a development going on in the West which many well-informed men believe to be of more importance to this country than the construction of the Panama Canal. Throughout the West there are thousands of people who have fought for its initiation and, having been successful, are now looking forward to its completion, and predicting, as a result thereof, the most remarkable era of advancement and prosperity that this country has ever beheld. In the East there is a bare handful of people who appreciate and understand; a few more have a vague, mistaken idea; but the vast majority of Americans east of Missouri River have no more information concerning it than they have with reference to the foreign policy of the King of Siam.

It has not been observed that this dearth of information upon the part of eastern people is confined to any one class or profession, and it has been a matter of surprise to find that so few eastern engineers, and especially those who have specialized in water-works construction, maintenance and operation, have thought it worth the effort to inform themselves concerning the greatest water-supply systems of the world, which are being constructed within their own country and which involve the expenditure of over thirty millions of dollars. This water-works construction is designed to change enormous areas in the Great American Desert

from places of desolation and whitened bones to places of prosperous homes and fertile fields, where millions of people will dwell, and where generations of Americans will grow up. It involves engineering projects in many respects unprecedented in magnitude, which have quietly and conservatively, but none the less quickly and definitely, been entered upon, and are even now in process of construction.

Two fifths of the area covered by the United States is arid. This statement means that upon that proportion of all our possessions exclusive of Alaska and insular territory, sufficient rain does not fall to make agriculture profitable. Some of this area is in the semi-humid belt, where there may be for a season rain enough to provide for the growth and maturity of a crop, but where, perchance, the season or successive seasons following will bring little or no moisture. Some of it is desert, extending mile upon mile in blinding white solitude without the semblance of a living thing. Some of it is wind-swept plain, as level as the ocean and quite as featureless, differing from the desert only by reason of its growth of hard, dry, woody grass, its knots of sage-brush, its mesquite bushes or its cacti. There is upland and mountain, canyon and mesa, and all is devoid of useful vegetation as the paved streets of an eastern metropolis. This barren principality is greater than the empire of ancient Rome, seven times as large as the domain of the German Emperor, and equal to thirty states of the size of New York. Much of this region must always remain in its present condition, but there are enormous tracts throughout the length and breadth of the arid belt which retain every requisite feature of climate and fertility save that of moisture.

On June 17, 1902, the United States Congress passed the Reclamation Law. It provides that all the moneys received from the sale of public lands shall be set apart for the construction of irrigation works. The experience of years had shown that it was the only possible means whereby millions of acres of desert waste could be made habitable, and upon which there might develop communities which would return to the country an added vigor and stability which would be a thousand fold more valuable than the money expended. In addition to this, it seemed especially fitting that the money received from the sale of public

lands should be expended in this way, because nearly all government land in the humid regions has been sold, and practically all that now remaining in government ownership is arid. The money so provided is not a gift to the arid belt, but a loan that draws no direct interest. The farmer who takes up public land in an irrigated area must pay for the cost of the irrigation system, or his proportionate part thereof. The payment must be made in ten annual installments without interest, and thus the Government is finally reimbursed for the actual expenditures made necessary by the construction of irrigation systems, and loses in the end only the theoretical interest on the money so used. At the end of the period of payment, the farmer is the sole owner of the water rights; they become appurtenant to his property. The law makes it one of the duties of the Secretary of the Interior to make examinations and surveys for appropriate irrigation works and to locate and construct them. He is further authorized to withdraw from entry all public lands which may be required for any system of irrigation, and also the land which may be irrigated from such system. The actual engineering work has been placed by the Secretary of the Interior under a corps of engineers which has been designated as the United States Reclamation Service.

A wise provision in the irrigation law is that which makes it necessary for the farmer to take up irrigated lands under the Homestead Act; that is, no single farm unit can consist of more than one hundred and sixty acres, and, to secure title, the farmer must be an actual resident upon the property.

This prevents enormous speculative operations by which companies or individuals with large capital may acquire tremendous tracts of lands, and thereby receive the benefits of government irrigation, to the exclusion of the individual provided with less initial capital. In other words, the terms of the statute were designed to provide for *homes* in the arid states, rather than to increase the values of the land for speculative purposes.

The location and the extent of the work already undertaken is set forth in Table No. 1. It will be seen that all of the states and territories represented in the arid belt are provided for with the exception of Oklahoma, in which reconnaissance work is now going on.

TABLE No. 1. IRRIGATION PROJECTS ALREADY UNDERTAKEN.

State.	Name of Project.	Acres Irrigable.	Allotment.
Arizona	Salt River	160 000	$3 850 000
California	Yuma	85 000	3 000 000
Colorado	Uncompahgre	100 000	2 500 000
Idaho	Minidoka	60 000	1 300 000
"	Payette-Boise	60 000	1 300 000
Kansas	Garden City	8 600	260 000
Montana	Huntley	30 000	900 000
"	Milk River	——	1 000 000
Montana *(½)	Lower Yellowstone	40 000	1 200 000
Nebraska and Wyoming	North Platte	100 000	3 330 000
Nevada	Truckee-Carson	120 000	3 000 000
New Mexico	Hondo	10 000	240 000
"	Carlsbad	——	600 000
"	Rio Grande	——	200 000
North Dakota (½)	Lower Yellowstone	20 000	700 000
North Dakota	Pumping plants	33 000	1 000 000
Oregon	Klamath	100 000	2 000 000
"	Umatilla	18 000	1 000 000
South Dakota	Belle Fourche	60 000	2 100 000
Utah	Strawberry Valley	25 000	1 250 000
Washington	Okanogan	9 000	500 000
"	Yakima	40 000	1 750 000
Wyoming	Shoshone	75 000	2 250 000
		1 153 600	$35 230 000

* For dam in St. Mary; will not irrigate any land.

It will be impossible to discuss within the time allotted for this paper the constructive features of all the projects named in this table. Therefore attention will be given to those which comprise the most interesting features.

SALT RIVER PROJECT, ARIZONA.

The area to be irrigated under this project lies in the lower valley of Salt River in the region about Phœnix, Tempe, and Mesa, while the storage reservoir, the largest artificial lake in existence, lies to the northeast about seventy miles from Phœnix. The water stored in the reservoir is to be released as required for irrigation and allowed to flow down the bed of the river to a point near the head of the irrigated area, where it will be diverted into properly constructed canals. About 160 000 acres in this lower valley will be irrigated under gravity canals, while the remainder

will be provided for by pumping water on the higher levels with power derived from a plant located at the reservoir dam. The reservoir will cover what is known as the Tonto Basin, a great depression formed by the valleys of Salt River and Tonto Creek, the two streams joining a short distance above the dam site. (Plate I, Fig. 1.) The extreme length of this reservoir will be 25 miles, its greatest depth of water 230 feet, and its capacity 61 000 000 000 cubic feet, or about 456 000 000 000 gallons, sufficient to supply the Metropolitan water system in Massachusetts at the present rate of consumption for a period of ten and one-half years.

Salt River enters a canyon a short distance below the confluence of Tonto Creek. Across this canyon, at the section shown in Plate I, Fig. 2, a dam, known as the Roosevelt Dam, is in process of erection which will have a total height from foundation to top of parapet of 280 feet, and an effective storage height of 230 feet. (See Fig. 1.) The length of the dam at datum, or low water, will be 138 feet, and at the crest, 644 feet. The section of the dam provides for a masonry wall 158 feet thick at the base, tapering as indicated to a thickness of 16 feet at the crest. There will be about 300 000 cubic yards of masonry in the structure.

The dam has a gravity arch section, the radius being 400 feet. A roadway is carried over the dam, crossing the spillways on each side by concrete-steel arch bridges. The total height of the spillway above datum or mean low water will be 230 feet, while the roadway will be 20 feet higher. The spillways are each about 200 feet long, providing for a total discharge of 4 000 cubic feet per second. The specifications require that the masonry shall be of broken range cyclopean rubble, laid so as to break joints and be thoroughly bonded in all directions. The stone will be quarried from the walls on each side of the canyon for the spillways, and will be laid in cement mortar. The material is a tough, coarse-grained sandstone of a specific gravity of about 2.5. Samples of the stone crush at a pressure of from 1 000 to 1 800 tons per square foot, which affords an exceedingly wide margin of safety. The stone for the up-stream face will be selected so as to lie with horizontal beds and vertical joints in

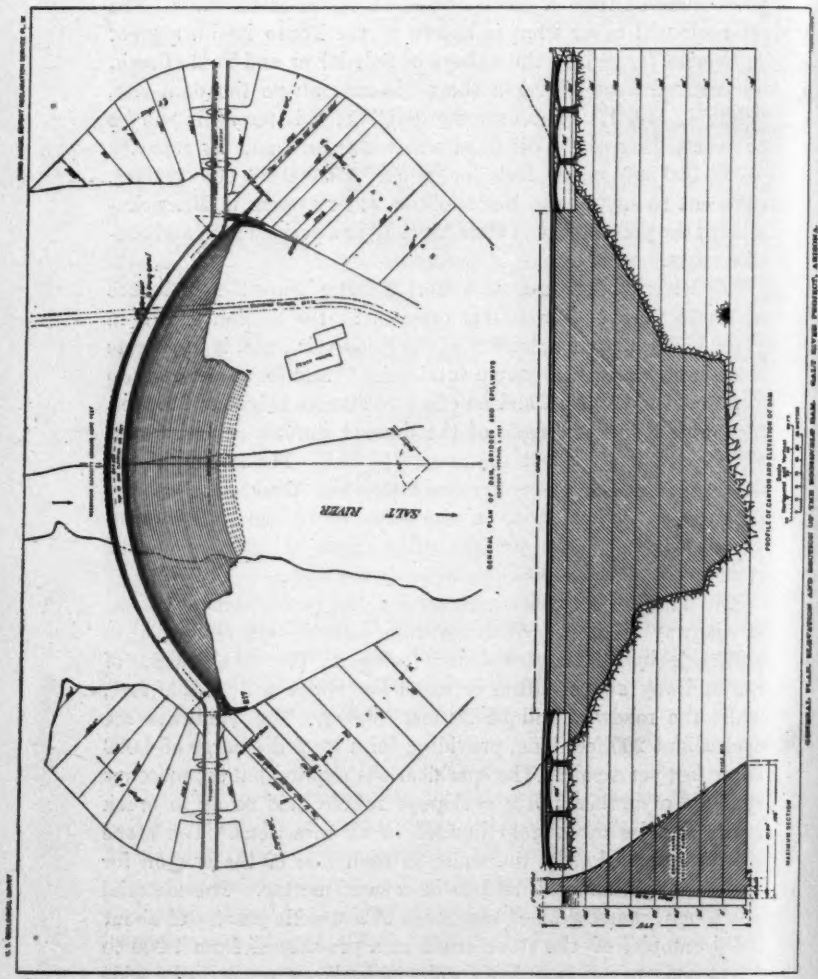

SALT RIVER
GENERAL PLAN OF DAM, BRIDGES AND SPILLWAY
PROFILE OF CANYON AND ELEVATION OF DAM
MAXIMUM SECTION
GENERAL PLAN, ELEVATION AND SECTIONS OF THE ROOSEVELT DAM. SALT RIVER PROJECT, ARIZONA.

FIG. 1.

FIG. 1. TONTO BASIN (SALT RIVER), ARIZONA.

FIG. 2. SITE OF ROOSEVELT DAM (SALT RIVER).

Portland cement mortar composed of one part Portland cement and two parts sand. Vertical joints between the stones inside of the face of the dam must nowhere be less than six inches. The concrete used in the construction of the dam is composed of one part cement, two and one-half parts of sand and four parts of broken stone. The term "sand" is interpreted as the run of the crusher which passes a quarter-inch screen, while "stone" is interpreted as that which passes a two-inch mesh.

In order to provide for the rights of prior appropriators, it is necessary to guarantee the release of a certain amount of water into the river channel at all times. To accomplish this and to utilize the power available at the dam site, a low diversion dam has been constructed across Salt River above the upper reaches of the overflowed areas, and in seasons of low water the entire flow of the stream will be diverted around the reservoir by means of a conduit 19 miles long. A part of this conduit is in heavy cut, some of it on fill, while 9 000 feet consists of tunnels, 15 in number, through clay, sand, quicksand, and solid rock. Fourteen of these tunnels are along the power canal and one is a sluicing tunnel at the dam site.

Tunnel No. 1 at the point of diversion is 1 700 feet in length and afforded more difficulties of construction than any of the others. For 600 feet it passed through bowlders that were imbedded in quicksand and varied from small cobbles to masses weighing several tons. As this sand would run like water, heavy timbering was provided. The finished section of this tunnel has a width of 9 feet and a height of 8 feet to the apex of the arch, but in order to allow for the timbers the excavation was made 12 feet wide and 11 feet high. Square sets of 10-inch timbers were placed two feet apart from center to center and inside each of these an arched set was placed for extra strength as well as to give a proper section to the tunnel. The breast of the tunnel had to be boarded solid and the lagging driven ahead for each following set. The greatest difficulty occurred when big bowlders were encountered. These had to be dealt with separately and worked an inch at a time, regardless of size or condition, as any attempt to break them with powder would have caused a cave or a run. This 600 feet of bad ground was worked with four

headings with 2 shifts each, and an average of 6 feet per day was made from the four headings.

Quicksand was encountered elsewhere in the work, but was not as difficult as at tunnel No. 1.

The last tunnel to be constructed was the penstock. This is a circular tunnel, 620 feet long and 8½ feet in diameter; it has a fall of approximately 200 feet from the mouth of the canal to the turbine. Before work was begun on this tunnel it was necessary to excavate, out of the perpendicular cliffs, a site for the power plant, which is 23 feet above the river. The tunnel starts at the back of the power plant at the elevation of the floor. Work was begun at the lower end of the penstock by hand, as floods in the river made the temporary power plant useless. For two months the materials and supplies were packed in on the shoulders of men, along precipitous canyon sides, shelving rock and rolling bowlders, and passed down the vertical cliffs by ladders and ropes. In this way 110 feet of the tunnel was driven. Later, after the floods had subsided, the work was carried on more expeditiously by means of power. Notwithstanding the fact that an exhaust fan with 7-inch piping was used, the heat and gas were intense. It is a peculiarity of this climate and elevation that all underground raises have no ventilation. In this tunnel the heat was unusual, due to the proximity of subterranean hot springs.

The sluicing tunnel around the base of the dam is 13 feet wide, 11 feet high, and 480 feet long, and it is carried through solid quartzite and sandstone. The heat here was intense and caused the death of two of the men; several hot springs were encountered and the temperature rose to 130° Fahrenheit, with practically 100 per cent. humidity.

The cost of the masonry construction of the dam is $3.15 per cubic yard, or a total for the entire structure of $1 147 600. This cost is exclusive of cement and sand, which are furnished by the Reclamation Service from the Government cement mill near the dam site, which will be described later. The total cost of dam, allowing $2.50 per barrel for cement, is over $2 000 000. The cost of the power tunnel was $26.50 per linear foot.

One of the best pieces of construction connected with the Salt River project is the sluicing tunnel and gates. (Fig. 2.) In

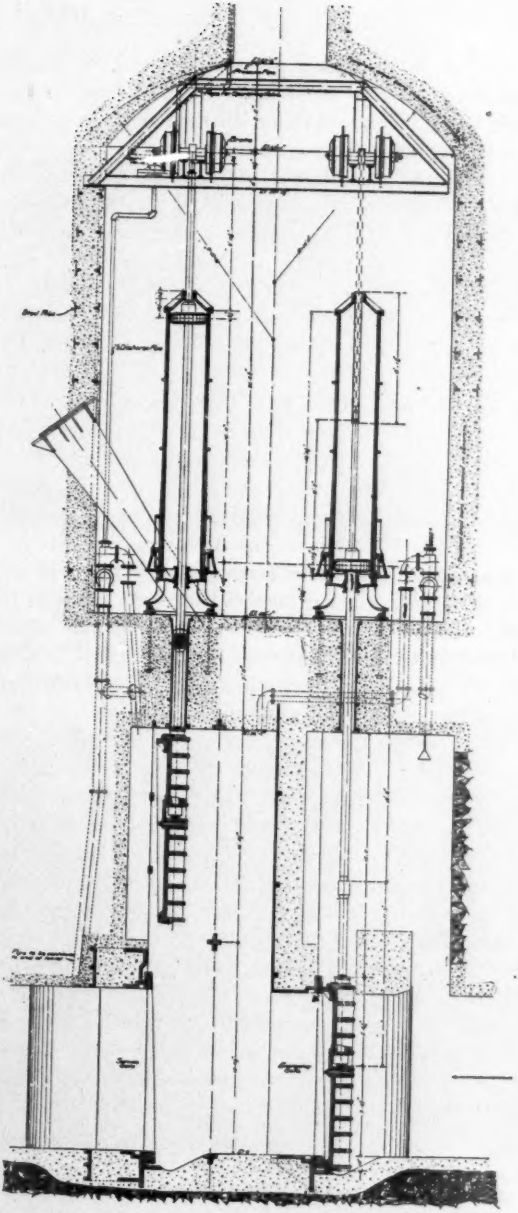


FIG. 2. SLUICING GATES AT ROOSEVELT DAM.

this tunnel will be placed six gates to be used for sluicing purposes and for regulating the flow of the water to the canals of Salt River Valley. These gates with their operating mechanism will weigh nearly 800 000 pounds, and will be the largest ever constructed to operate under the great pressure of 100 pounds per square inch. The pressure on each gate is about 800 000 pounds. With the reservoir full, these gates are capable of discharging 10 000 cubic feet per second. During the construction of the dam, the river will be diverted through this channel. It will not be possible in the time allotted for this paper to discuss the details of construction. Indeed, the subject is worthy of a separate paper.

One of the interesting features of this project is the Government cement mill, constructed near the dam site. It was not originally the purpose of the Reclamation Service to enter into the manufacture of cement, but it was found that the cost of cement shipped to this site would be prohibitive. The nearest railroad point is Globe, Ariz., which is not within easy access of any of the cement works. The freight rates to this terminal point are high, and the transportation overland for forty miles to the dam site would add excessively to the cost. The bids which were received for furnishing cement were $4.81 per barrel, delivered at the dam site. As the construction required 200 000 barrels of cement, the cost of the work would be prohibitive. It was found, however, that cement materials were available at or near the dam site; a good cement rock underlies the mill and suitable clay is available a short distance away. It was therefore decided to erect a mill, at a cost of $100 000. The cement manufacturers naturally objected to this move, but it was conclusively shown that if it were necessary to purchase cement at the price at which it could be delivered at the dam site, the cost of the structure would be wellnigh prohibitive, while the erection of the cement mill and the manufacture of the material upon the spot would result in an enormous saving. In view of the fact that cement manufactured at this mill costs $2.50 per barrel, the Government could hardly afford to haul purchased cement from Globe to the dam site, even if the material were delivered at Globe free of cost. The mill finally erected has a capacity of 350 barrels per day.

FIG. 1. UNCOMPAHGRE VALLEY UNDER IRRIGATION.

FIG 2. SITE OF PATHFINDER DAM (NORTH PLATTE RIVER).

The chief item of expense is that of fuel, it being necessary to haul oil in wagons from Mesa, Ariz., a distance of about fifty miles. Average results of tensile tests of neat cement briquettes are: 478 pounds after seven days (one day in air and six days in water); 552 pounds after fourteen days.

The Uncompahgre Project.

The Uncompahgre Valley comprises an area in Ouray, Montrose, and Delta counties in the southwestern part of Colorado. It is watered by Uncompahgre River, which flows northward and joins Gunnison River at Delta. In this valley there are about 75 000 acres which early experience proved to be exceedingly fertile under irrigation. (Plate II, Fig. 1.) Consequently, in about 1884 settlers flocked to the valley and filed upon nearly all the land in the region. Irrigation canals were constructed and what was believed to be a mighty era of prosperity was begun. It was soon found that all this development was made without any idea of the amount of water in Uncompahgre River available for irrigation. The river did not begin to furnish sufficient supply. After a time great tracts were deserted, costly improvements abandoned, and the acres under cultivation soon dwindled to 30 000.

Thirty miles eastward from Uncompahgre River and flowing nearly parallel to it is the Gunnison (Fig. 3), which farther to the north takes an abrupt westward turn and is joined by the Uncompahgre at Delta. Along this portion of the Gunnison parallel to the Uncompahgre, the river traverses the Grand Canyon (Plate III, Fig. 1), one of the best scenic features of the West, and at the same time one of the most difficult places of access.

The method of solution of the Uncompahgre problem which found most favor was the tapping of the Gunnison by a tunnel opening at the bottom of this canyon and extending underground six miles to a point in the Uncompahgre Valley from which the water could be carried in open canals. Up to the time of the official investigation nothing was known concerning Gunnison Canyon save that its walls rose sheer 3 000 feet, that a torrential stream ran through the bottom, and that it was impassable. So far as was known, no man had ever passed through

this canyon alive. It was necessary to know, first, the conditions existing in the canyon and whether or not, were all the other difficulties overcome, it would be possible to open a tunnel heading. A voyage through the canyon was necessary, and

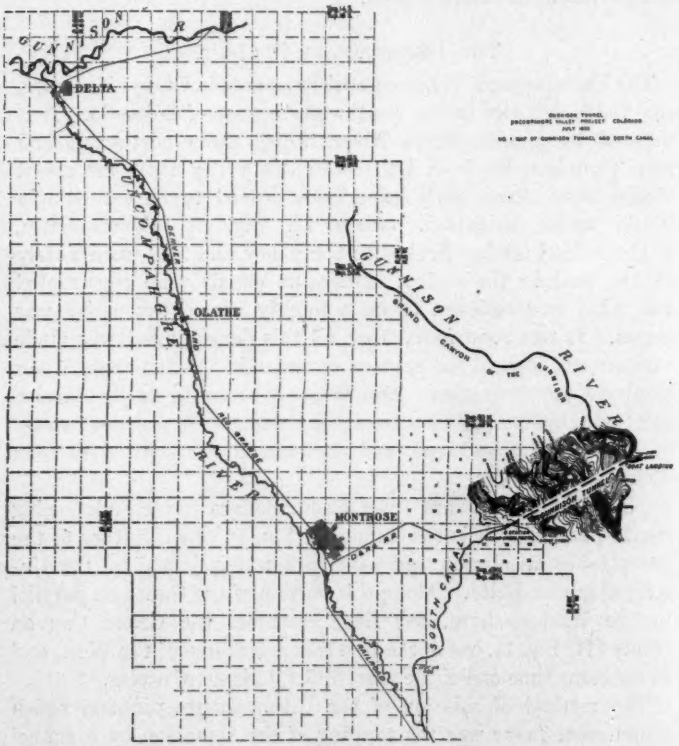


FIG. 3. MAP SHOWING LOCATION OF GUNNISON TUNNEL.

it was undertaken and accomplished by Mr. A. L. Fellows, at that time district engineer for Colorado. In spite of the difficulties and dangers attendant upon the journey, Mr. Fellows' observations resulted in the selection of a heading just above the point at which the canyon boxes up.

FIG. 1. CANYON OF THE GUNNISON.

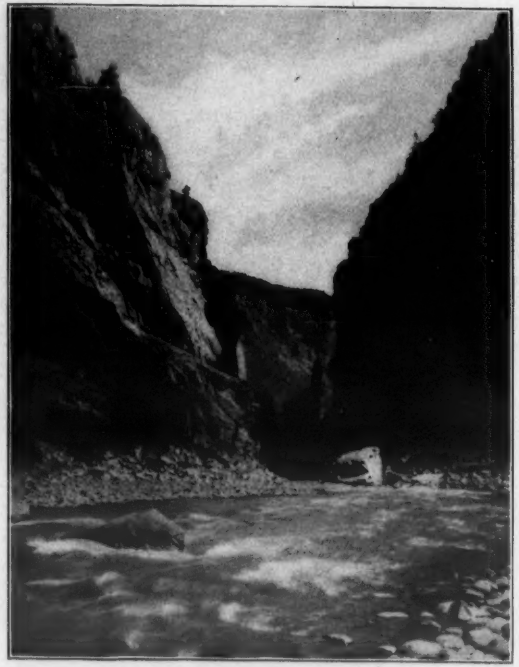


FIG. 2. SITE OF SHOSHONE DAM.

PLATE III.

In Fig. 4 is shown the tunnel profile. When finished it will be 30 582 feet long, and of a capacity of 1 300 cubic feet per second. The total excavation will be 183 500 cubic yards, of which 93 000 cubic yards will be in rock. The total amount of lining will be 30 000 cubic yards, laid at a cost of $6.75 per cubic yard. The cost of the tunnel and other rock is $40 per linear foot, while the total cost of the tunnel will be $1 200 000.

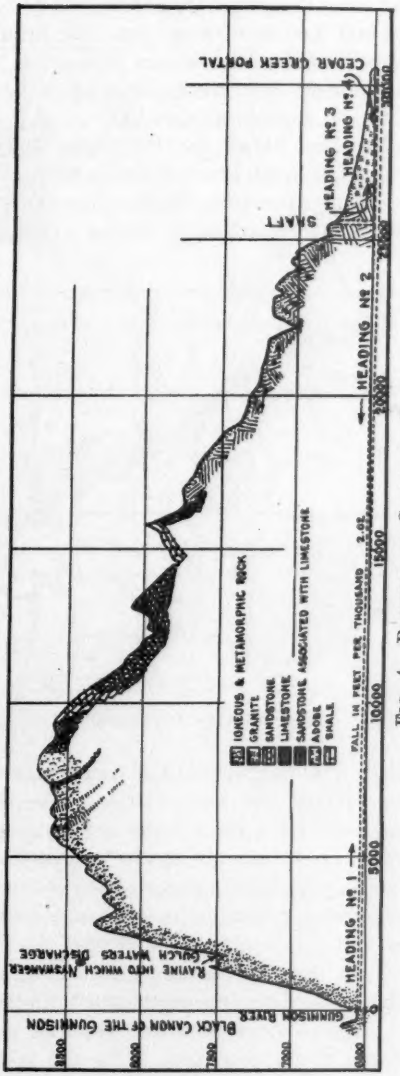


FIG. 4. PROFILE OF GUNNISON TUNNEL.

NORTH PLATTE PROJECT.

The land to be irrigated under the North Platte project lies in southeastern Wyoming and western Nebraska along the North Platte River Valley, as shown in Fig. 5; the total acreage irrigable will be 100 000. The water is to be conserved in the Pathfinder reservoir,

and, being discharged from there, will flow sixty miles in the stream bed and then be diverted into the Interstate Canal, which conducts the water into the area in question. The point of interest in this project from the engineering standpoint is the Pathfinder Dam and appurtenant works.

The dam called the Pathfinder Dam is located across the channel of North Platte River in Wyoming, three miles below the mouth of Sweetwater River, where the Platte enters the canyon cut through Rattlesnake Range. (Plate II, Fig. 2.) Here the

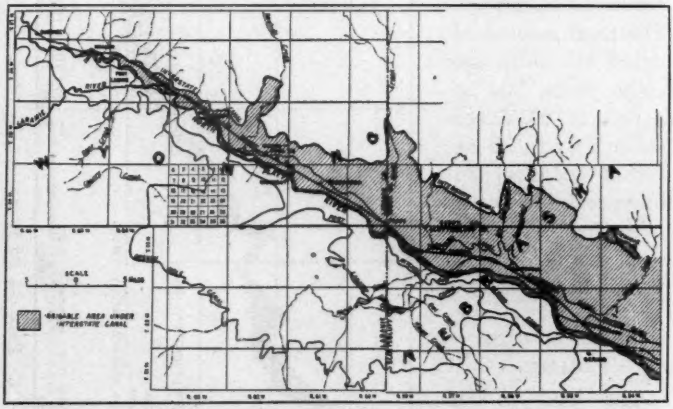


FIG. 5. MAP SHOWING INTERSTATE CANAL, NORTH PLATTE PROJECT.

gorge is 80 feet wide at low-water mark and but 180 feet wide at a point 160 feet above Datum. The walls are of solid granite, and bed rock without seam or fracture occurs 10 feet below low-water mark. Fig. 6 shows a cross-section of the gorge with dam in place, and a cross-section of the dam which is being constructed of granite in broken range cyclopean rubble. The total amount of masonry will be 53 000 cubic yards. The specifications provide that the masonry shall be laid so as to break joints and thoroughly bond the work in all directions. The stone used is as large as practicable, and facilities are provided for handling stones weighing ten tons. The aim is to use in the construction

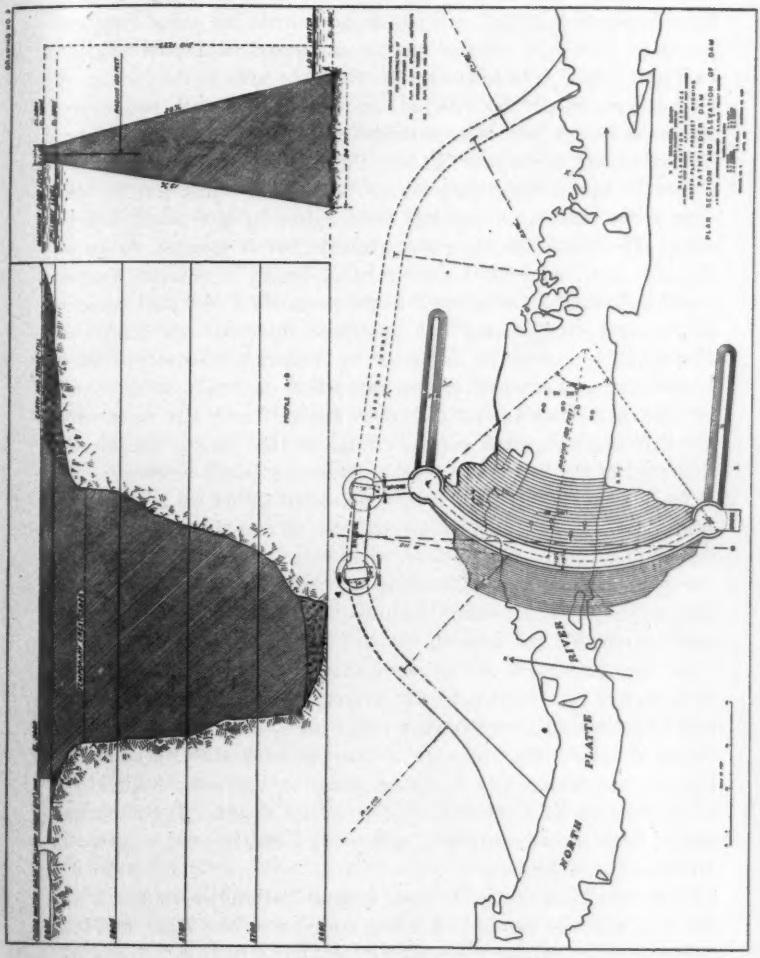


FIG. 6. PATHFINDER DAM.

of the dam the largest proportion of stone and the smallest proportion of mortar and concrete. The stone for the up-stream face is selected so as to lie with horizontal beds and vertical joints in Portland cement mortar composed of 1 part cement to 2 parts sand. At least one fourth of the area in the face must be headers, evenly distributed throughout the wall, and every header must be laid over a stretcher of the underlying course. The stretchers must not be less than 3 feet long nor less than 2 feet in any other dimension. The headers must not be less than 6 feet in length nor less than 2 feet in any other dimension. The stone for the down-stream face is selected so as to lie with horizontal beds and vertical joints in cement mortar composed of sand and cement in the proportion of 1 part cement to 2½ parts sand, where not otherwise directed. At least one fourth of the area in the face must be headers. All concrete used in the dam is composed of the proportion of 1 part cement and 2½ parts sand and 4 parts of broken stone of such size as to pass through a 2-inch mesh screen. Sand in this case is considered that part of the run of the crusher passing a ¼-inch screen.

The dam (Fig. 6) is of arch type, constructed on a radius of 150 feet. It is 10 feet thick at the crest, 94 feet thick at the base, and 210 feet high. The batter of the up-stream face is 0.15 and of the down-stream face, 0.25. The masonry is reinforced by steel rails at points at and below the crest where special horizontal and vertical stresses will develop.

In may be considered by some that this dam is of very thin section, but it conforms to the principles established by a long series of elaborate experiments made under the direction of the board of consulting engineers of the United States Reclamation Service, the work being executed under the immediate direction of Mr. George Y. Wisner, a member of the Board. For a discussion of these experiments see *Engineering News*, issue of August 10, 1905, p. 141 *et seq*.

The maximum depth of water behind Pathfinder Dam will be 200 feet, and the amount of water stored will be 326 000 000 000 gallons. The contract price for the complete structure is $582 000. As will be noted upon the plan, the outlet of the reservoir will be through a tunnel cut through the walls of the canyon, and

through this the river is diverted during construction. The spillway is provided on the right bank of the canyon so that the dam is a solid structure without gates or openings, and no water will flow over the top.

The Shoshone Project.

This project contemplates the storage and diversion of a portion of the surplus water of Shoshone River in Wyoming for the reclamation of public lands lying on the north side of the river, extending from the mouth of the Shoshone Canyon down stream about 50 miles, covering an area of approximately 282 000 acres. The present development is proposed to reclaim only 125 000 acres. Just below the junction of its two forks, Shoshone River enters a canyon 3 miles in length, 1 mile of which is cut in solid granite with nearly vertical walls, and it is about 65 feet wide in its narrowest places. The point selected for the dam site (Plate III, Fig. 2) is 70 feet wide on the bottom of the channel and 200 feet wide at an elevation of 240 feet, the proposed height of the dam above the river bed. (Fig. 7.) This provides for a dam of a height from lowest foundation to capstone of from 305 to 310 feet, it being the highest dam in the world, both in total height and effective storage height. The capacity of the reservoir formed thereby will be 14 858 000 000 gallons, or a little less than one half of the storage capacity afforded by the Pathfinder Dam and a little more than one third that afforded by the Roosevelt Dam. The spillway will be 250 feet in length, the weir being located a few hundred feet below the dam on the side of the canyon, and connection therewith from the reservoir will be made by the construction of a spillway tunnel of a capacity of 10 000 cubic feet per second.

A tunnel for the public highway will be cut out of the same side of the canyon and will cross this spillway tunnel twice at an elevation of about 45 feet above the average elevation of the spillway tunnel floor. The dam as shown in the illustration will be of the arch type upon a radius of 150 feet. (Fig. 8.) It will be noted that the dam is being constructed 108 feet thick at the base and 10 feet thick at the crest, with an up-stream batter of 15 per cent. and a down-stream batter of 25 per cent.

As shown upon the illustration, a vertical section of the dam having an effective storage height of 31 feet will be constructed in advance of the main portion for the purpose of diverting water from the excavation. The section of this dam is based upon experimentation in the same way as has been discussed in the

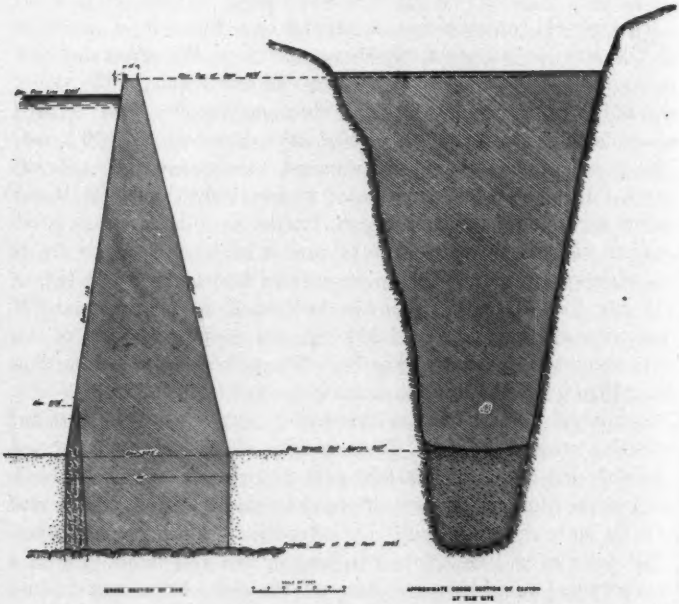


FIG. 7. SECTION AND ELEVATION OF SHOSHONE DAM.

case of the Pathfinder Dam, a thin section with an uncommonly large up-stream batter for this kind of structure.

The dam is being constructed of concrete of a composition, where not otherwise specified, in the proportion of 1 part cement, 2½ parts sand, and 5 parts of broken stone. The term "sand" is interpreted as that portion of the run of the crusher which shall pass a screen of ¼-inch aperture, the proportion of finer particles being such that the void in the dry aggregate shall not exceed 30 per cent. of the mass. The stone used in the crusher

is granite taken from the sides of the canyon and other suitable places. The concrete will be reinforced by steel and iron rails in such portions of the dam as will by reason of horizontal and vertical stresses require such reinforcement. It is provided in

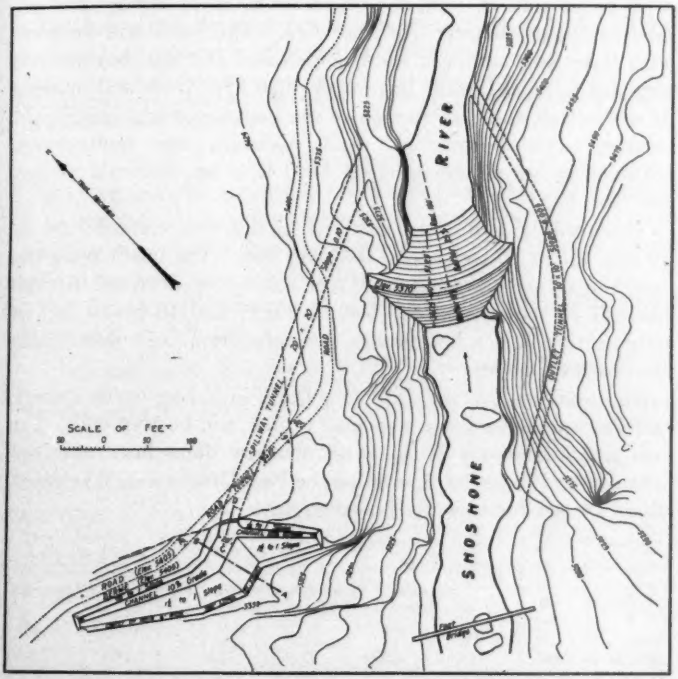


FIG. 8. PLAN OF SHOSHONE DAM AND TUNNELS.

the specifications that both faces of the dam shall be molded against forms of dressed tongued and grooved timber placed to conform to lines established by the engineer. The concrete shall be so placed against these forms and so manipulated as to secure a smooth, dense, and uniform facing of the dam. The contract further provides that in the freshly deposited concrete

the contractor shall place by hand pieces of granite weighing between 25 and 200 pounds, which shall be rammed until well bedded. The proportion of such rocks shall be as nearly as possible uniform throughout the dam and shall form at least 25 per cent. of the total volume of masonry. No such rock shall be in contact with any other or within 6 inches of either face or either abutment of the dam. The work will be done with three daily shifts of eight hours each, and the contractor is required to adopt means to provide such appliances and housing as will permit the construction of the masonry work during cold weather. Such provisions shall maintain the temperature within 6 inches of the concrete until it is ten days old at not less than 32° F.

There will be two outlet conduits leaving the reservoir, one at 10 and one at 60 feet above the river bed. The one leaving the reservoir at the elevation of 10 feet will be by a tunnel through the side of the canyon 500 feet in length and 10 by 10 feet in cross-section, and will discharge the water from the reservoir into the low-level canals.

The total cost of the Shoshone Dam, including outlet tunnel, spillway tunnel, spillway and road tunnel, will be $600 000. The cost and dimensions of the three masonry dams here described compared with similar figures for the New Croton and Wachusett dams are set forth in the following table:

TABLE No. 2.

	Roosevelt Dam.	Pathfinder Dam	Shoshone Dam	New Croton Dam	Wachusett Dam
Length at crest	650	226	175	1 168	850
Height above foundation	280	210	308	297	207
Maximum effective storage height	230	190	240	157	185
Thickness at base	158	94	108	206	185
Thickness at crest	16	10	10	18	25
Cu. yds. of masonry	350 000	53 000	69 000	833 000	280 000
Capacity of reservoir (million cu. ft.)	61 000	43 560	19 863	4 000	8 400
Cost of dam	$2 000 000	$600 000	$700 000	$7 600 000	$2 000 000
Cost of dam per million cu. ft. stored	$32 80	$13 78	$35 25	$1 900 00	$238 10

It should be explained that the last entry upon this table does not represent the cost of storage per million gallons, but is based solely upon the cost of the dam. The total cost for storage in the Roosevelt basin, exclusive of power conduit and appurtenances, will be about $2 500 000, in which only about $85 000 is for land damages. In the case of the Wachusett Dam, the figure here given for cost per million gallons must be multiplied by about 4 to cover cost of entire reservoir.

NOTE. — The Belle Fourche Project and the large earthern dam to be erected in connection therewith are described in *Engineering News*, February 22, 1905, p. 210, and *Engineering Record*, March 3, 1905, p. 307.

DISCUSSION.

MR. CHARLES W. SHERMAN. I should like to ask Mr. Leighton if he can tell us something about the run-off of those streams, and how much water they can depend upon collecting per square mile of drainage area, or something of that kind.

MR. LEIGHTON. The run-off at some of the principal arid land stations is as follows:

TABLE NO. 3. RUN-OFF OF RIVERS IN THE ARID REGION — FOR THE YEAR 1904.

Stream.	Station.	Second Feet per Sq. Mi.	Depth in Inches.	Drainage Area Sq. Mi.
Salt River	Roosevelt, Ariz.	.057	.785	5 756
Verde River	McDowell, Ariz.	.062	.843	6 000
Colorado River	Yuma, Ariz.	.062	.844	225 049
Gunnison River	Cory, Col.	.328	4.47	5 233
Humboldt River	Palisade, Nev.	.109	1.48	5 014
" "	Oreana, Nev.	.021	.288	13 800
Truckee River	Vista, Nev.	1.30	17.72	1 519
Carson River	Empire, Nev.	.737	10.02	988
Rio Grande River	San Idlefonso, N. Mex.	.071	.972	14 050
North Platte River*	Mitchell, Neb.	1.113	1.208	24 400
Milk River	Malta, Mont.	.028	.374	14 044
Shoshone River	Cody, Wyo.	1.28	17.44	1 480
Yellowstone River	Livingston, Mont.	1.286	17.523	3 580
Snake River	Minidoka, Ida.	.559	7.61	22 600
Palouse River	Hooper, Wash.	.382	5.20	2 210

* Eight days in January; sixteen in February; five in March, not included.

It may be of interest to compare the run-off of some of these rivers with some in the East.

TABLE NO. 4. COMPARISON OF RUN-OFF OF RIVERS FOR THE YEAR 1904.

Stream.	Station.	Second Feet per Sq. Mi.	Depth in Inches.	Drainage Area Sq. Mi.
Yellowstone River	Livingston, Mont.	1.286	17.523	3 580
Connecticut River	Orford, N. H.	1.32	16.41	3 305
Palouse River	Hooper, Wash.	.382	5.20	2 210
Hudson River	Ft. Edward, N. Y.	1.97	26.74	2 800
Shosnone River	Cody, Wyo.	1.28	17.44	1 480
Mohawk River	Little Falls, N. Y.	2.27	30.96	1 306
North Platte River	Mitchell, Neb.	1,113	15.208	24 400
Susquehanna River	Harrisburg, Pa.	1.350	18.320	24 030
Verde River	McDowell, Ariz.	.062	.843	6 000
James River	Cartersville, Va.	.734	9.980	6 230

MR. FRANK L. FULLER. I should like to ask with regard to the evaporation from those lakes.

MR. LEIGHTON. That is one of the very important questions with which the Reclamation Service has to deal. Especially in the southern country, like Arizona, the evaporation is enormous,

TABLE NO. 5. EVAPORATION FROM WATER SURFACE, IN INCHES.

	Arizona, 1890.	Yuma, Ariz., 1904.	Sweetwater, Cal., Dam, 1898.	Lake Tahoe, Sierra Nevada Mts., Cal., 1901.	El Paso, Texas, 1890.	Santa Fé, N. M.	Salt Lake City.
January	3	3.6	1.747	0.84	2.0	3.0	1.8
February	4	3.9	2.671	0.70	2.0	3.4	2.7
March	6	6.19	4.249	0.77	7.0	4.2	3.6
April	7	9.37	5.351	1.25	7.3	6.8	7.2
May	10	9.94	5.611	2.42	10.8	8.8	6.9
June	11	10.11	7.193	3.35	11.7	12.9	8.9
July	12	10.19	8.153	——	9.6	9.2	9.2
August	13	7.87	8.141	6.50	7.6	9.8	10.7
September	10	6.38	7.239	4.12	—	6.6	9.6
October	6	7.02	4.999	2.65	—	6.7	6.5
November	5	4.41	4.012	2.09	3.7	5.7	5.0
December	4	1.91	.867	1.44	3.0	2.7	2.3
Total	91	80.89	60.233	*26.13	—	79.8	74.4

* Eleven months.

and it becomes an important item in calculating the amount of water available from storage. The following figures may be of interest. Evaporation is given in inches per year from water surfaces.

MR. FULLER. Can you tell us what the average rainfall is for a series of years?

MR. LEIGHTON. The United States Weather Bureau reports for 1904 the precipitations in arid regions as follows:

TABLE NO. 6. RAINFALL IN THE ARID REGION, 1904.

	Precipitation for Year.	Departure from Normal.
El Paso, Texas	11.30	+1.96
Santa Fé, N. M.	14.19	—0.09
Phœnix, Ariz.	5.57	—1.38
Yuma, Ariz.	1.43	—1.55
San Diego, Cal.	6.61	—3.98
Spokane, Wash.	13 97	—4.35
Grand Junction, Col.	6.63	—1.90
Winnemuca, Nev.	9.44	+0.93
Salt Lake City, Utah	16.31	+0.07
Boise, Ida.	14.08	—0.40
Carson City, Nev.	10.52	—1.50

It should be stated with reference to the arid lands generally, that the precipitation, from an agricultural point of view, is not even as useful as would appear from the above figures, because in many places the rain comes in short periods and in great quantity, with long dry seasons intervening.

MR. JOHN C. WHITNEY. I should like to ask the speaker what the special object was of distributing those large fragments of granite throughout the concrete construction shown.

MR. LEIGHTON. Such construction is familiarly known as rubble concrete, or, in such structures as the Shoshone Dam where the stones are of large size, a more comprehensive term is cyclopean rubble concrete. The main object is to increase the weight of the dam and thereby increase its stability. The specific gravity of granite is greater than that of concrete. There is an important economic feature, too, in such construction, because the rock is usually cheaper than the cement materials

and the cost of the structure is decreased by a proportionate amount. In all the contracts let by the Reclamation Service, cement is provided by the Government, and the contractor submits bids without taking cement into consideration. Therefore, you can readily see how advantageous it is to put large stone blocks into the structure, where rock is cheap. Twenty-five per cent. of the entire structure of Shoshone Dam will be of stone. As the formula for the concrete is 1 part cement, 2½ parts sand, and 5 parts stone, and there will be 70 000 cubic yards in the dam, it would require a little over 96 000 barrels of cement for the entire structure, if it were built of concrete, but, inasmuch as 25 per cent. of the dam will consist of stone, there will be saved 24 000 barrels of cement by using this method.

MR. SIDNEY SMITH. When the storms do occur, when the rain falls, do the streams not carry a large quantity of detritus, and has any arrangement been made to relieve the reservoir of that?

MR. LEIGHTON. They do carry enormous amounts. Some of the engineers who were working on Gila River used to state in a joking fashion, when they came back to Washington, that it was hard for them to distinguish between mud and water. By placing a stick upright in the material they could decide, because if it was mud the stick would stand up, and if it fell over, they knew it was water. (Laughter.) The fact that the streams do carry these great amounts of sediment presents another very perplexing problem for the Reclamation Service. Of course, the accumulation in a reservoir reduces the effective storage capacity. The Salt River reservoir, for example, will probably lose a large proportion of its capacity in, say, sixty years, and the reason for extending the dam 10 feet higher was to postpone the day when remedial measures would be necessary. In all such cases, there have been provided enormous sluicing gates, through which the accumulations may be removed. Ground sluicing may be necessary to clear the reservoir in a large measure of this sediment. Lake McMillan, in New Mexico, which is a reservoir built by a private company, has lost a very large percentage of its storage capacity, and that is not yet a very old reservoir. But in every case, as I say, provision for sluicing is made. It may be necessary once in a generation and the cost will be high, but

such cost will be insignificant in proportion to the benefits of the reservoir and of the irrigation system, so that the property will easily afford the expense.

MR. SMITH. Will the cleaning out of the reservoirs at such times involve an expense to the owners of the land who use the water?

MR. LEIGHTON. Yes, sir. In ten years the property goes into the hands of the farmers, or, more correctly, into the control of the Water Users Associations, and they will maintain it thereafter. Those expenses will be provided for probably by the establishment of a sinking fund.

MR. FULLER. I should like to ask Mr. Leighton if it is necessary that this water, as it is used for irrigating, shall be reasonably free from sediment, or what the fact is with regard to it?

MR. LEIGHTON. No. If the sediment is properly handled, if it is merely what we call silt, it is a benefit to the property. You see the great portion of that country is sand, gravel, and coarse material, which is benefited by these deposits of silt. Take the Colorado River, for example, that is in a good many ways exactly similar to the Nile in its annual inundations and deposits of silt, and it has made the barren sand so rich that one farm hand cannot take care of more than 10 acres of land, because the crops grow so fast. They are raising all sorts of tropical fruits and have had considerable success lately with date palms, pomegranates, figs, almonds, and such things.

THE PITOMETER AND ITS USES.

BY EDMUND M. BLAKE, CIVIL ENGINEER, BOSTON, MASS.

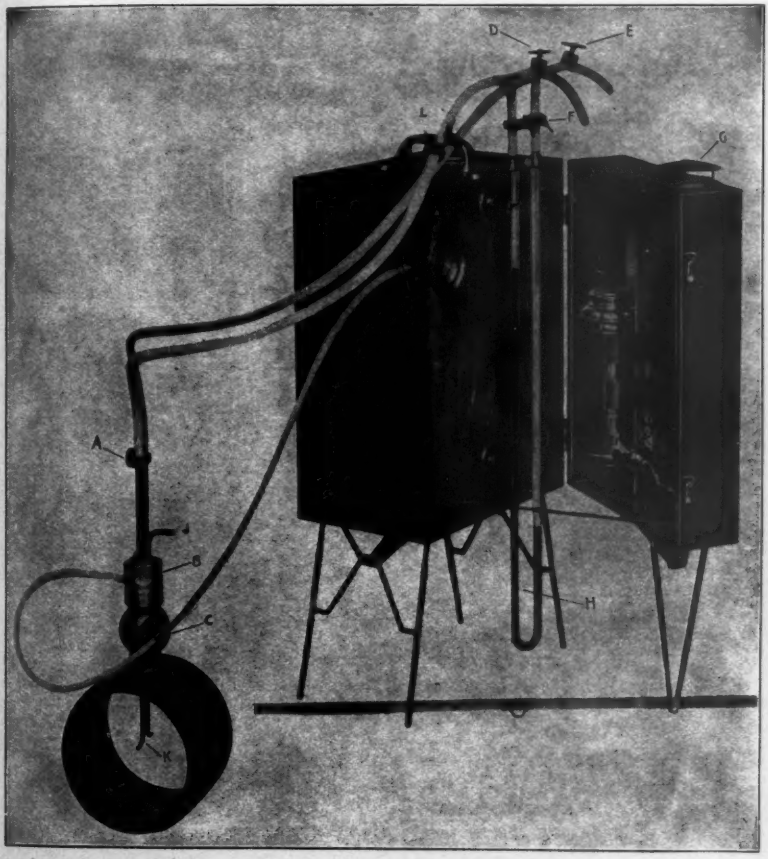
[*Read March 14, 1906.*]

In 1896, John A. Cole, consulting engineer of Chicago, found it necessary to make a water-waste survey at Terre Haute, Ind. He decided that it would be advisable to find some more economical method of measuring the waste flow than by use of the Venturi or Deacon meter. Edward S. Cole, associated with his father, finally acted upon a suggestion obtained from Prof. R. C. Carpenter's work on "Experimental Engineering," regarding the Pitot tube as applied to water mains. The use of the Pitot tube in open stream work is doubtless familiar to all engineers and superintendents.

Mr. Cole had to contend with many difficulties in adapting this principle to the measurement of velocities in closed pipes. Two tubes were finally adopted which could be introduced through a 1-inch corporation cock by means of a special cap, each tube with a hook bent 90 degrees and provided with a "cut-water." The two points of contact with the current are called orifices — one points down stream and the other up stream, as shown in Fig. 1. Many long series of calibrations were made with orifices and tubes of various diameters, but finally a choice was made of an orifice having an internal diameter of $\frac{1}{8}$-inch, made of 3-16-inch brass tubing, fitted to $\frac{1}{4}$-inch tubes. It was found that an orifice and tube of this size gave more reliable indications at low velocities, and that there was less trouble with negative readings or failure to return to equilibrium at no flow.

A glass U-tube, 22 inches long and having an internal diameter of $\frac{5}{16}$ inch, was used. Connections were made by $\frac{1}{4}$-inch rubber tubing, and a blow-off was located at the top of each connection to remove air. The lower half of the U-tube was filled with a mixture of carbon tetrachloride and gasoline, with a specific gravity of 1.25 or 1.50 at ordinary temperatures. For high

PLATE I.



THE PITOMETER WITH PHOTO-RECORDER.

velocities mercury is used. Careful notes were made of the temperature at which observations were taken, and temperature corrections were applied where found necessary. Plate I shows a complete pitometer set up, with the " orifices " in position in a section of water pipe.

It was found that photography was the only practicable means of registering continuously the deflections in the U-tube, without interfering with those deflections. The photo-recorder combines, upon one photographic diagram, a record of the static variations

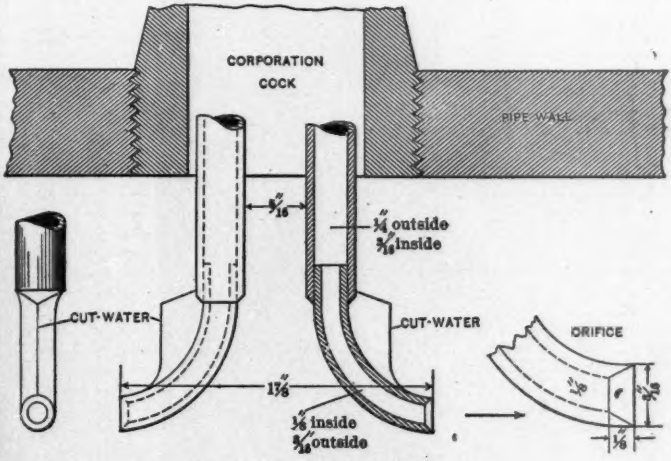


FIG. 1.

within the pipe with a record of the U-tube deflections, the latter, of necessity, being half deflections, as shown on the U-tube. The instrument has shown itself capable of producing a good continuous record upon ordinary Velox paper. Plate II is a sample of such a record. Notches in the slit through which the light passes on its way to the paper are so located that they produce horizontal rulings upon the record, corresponding to the calibrated deflections taken from the curves (Fig. 2). The combination of static pressure variation with velocity aids in interpreting the cause of any given variations in the flow.

It is first necessary to ascertain, by an operation called a "traverse," the relation between the average velocity in the main and the highest velocity, which is usually at or near the center. This

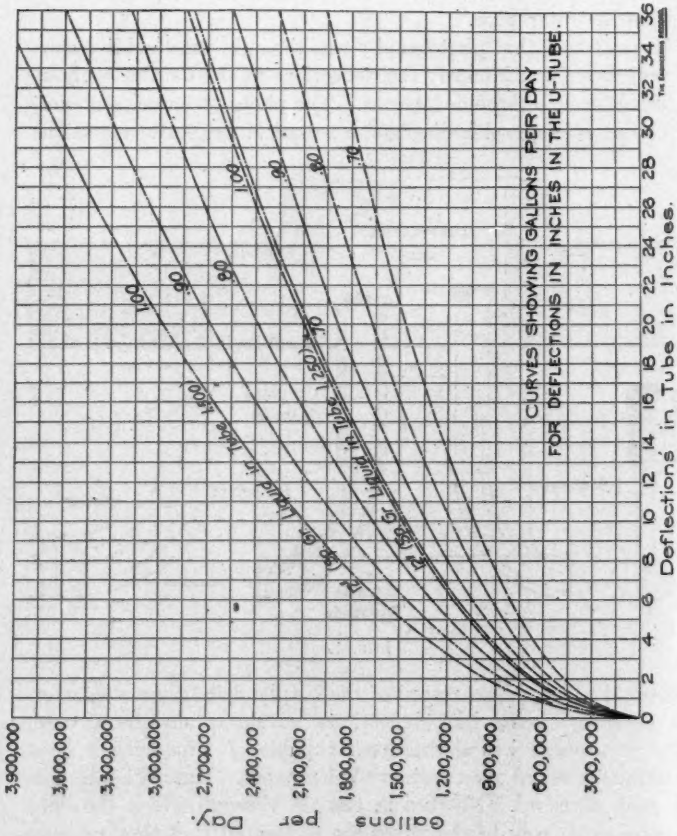


FIG. 2. CURVES SHOWING RELATION BETWEEN DEFLECTION IN U-TUBE AND QUANTITY OF WATER FLOWING.

relation varies considerably, according to the age of the main and the material of which it is made. When this relation — called the coefficient of the pipe — is ascertained, the orifices are

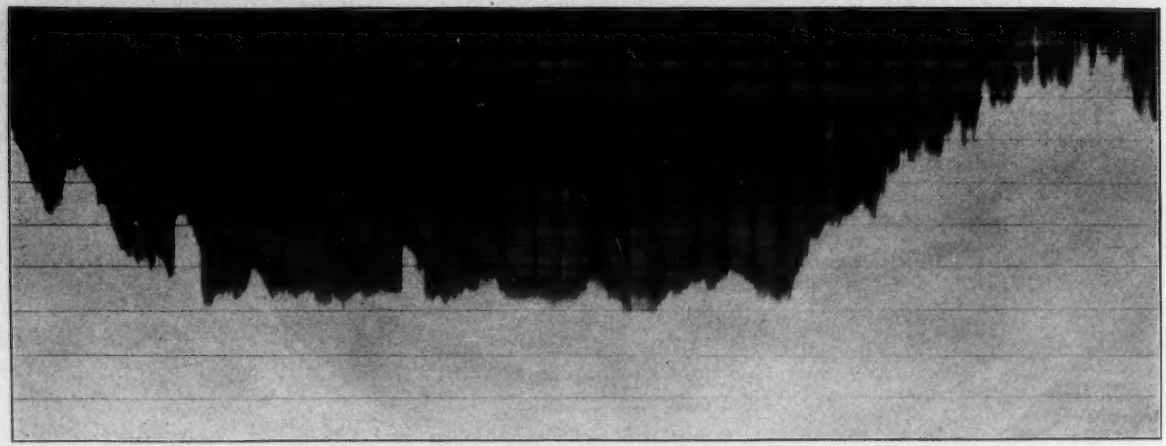
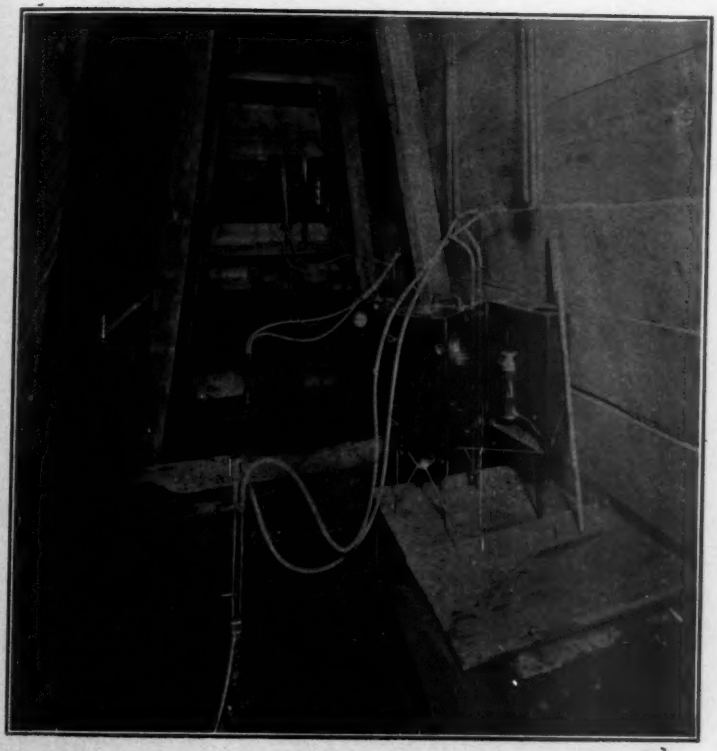


PLATE II.

PHOTO-RECORD OF THE CONSUMPTION IN A PURELY RESIDENCE DISTRICT OF COLUMBUS, OHIO. POPULATION OF DISTRICT, 46 000. THE RECORDED PER CAPITA CONSUMPTION AT NIGHT EQUALS 1.6 GALLONS PER HOUR.

PLATE III.



THE PITOMETER IN USE.

then set at the point of greatest velocity and remain there throughout the test.

The greater the velocity in the main, the greater the force with which the water impinges against the up-stream orifice, and it is the function of the metallic tubes, the rubber connections and the glass U-tube to communicate this pressure to the surface of mercury, or other liquid heavier than water, which will thus be depressed in one arm of the U-tube in accordance with this varying pressure. In order to make a permanent record of the movement of this liquid, the photo-recorder photographs the liquid upon a drum, which revolves steadily, thus showing a line on a sheet of paper which can be interpreted into gallons for any minute or hour of the day or night.

The pitometer, when thus used with a photo-recorder, registers automatically all the variations in velocity which take place in a water main. It is the only meter which can be used at will on all sizes of mains. It is portable and may be readily attached to any water main by means of a 1-inch corporation cock. A 1-inch reamer should be run entirely through the corporation and the key before placing it in the main. The location should be in a straight run of pipe, at least 50 feet, if possible, from all disturbing valves, bends, tees, etc. A less distance may be safe if the velocity is below 3 feet per second.

The uses of the pitometer may be classed under three heads, viz., engine tests, district surveys, and street inspections.

Engine Tests. The first work done is usually that of making a test of the pumping engines, or, in case of gravity works, of the reservoir flow. This indicates the deduction which must be made from station logs for slip of pumps or defective formulæ.

This test alone is often found to be one of great significance. Frequent slip-tests are of great utility, and if all works were equipped, it would enable the engineer in charge to make these himself at regular intervals.

District Surveys. The next step is usually that of dividing the area of the entire city into large districts. The flow of water into each of these districts is ascertained by the photo-recorder on a continuous run of several days and nights, including, if

possible, a Sunday. From these records, which show the use for every hour, a comparison is made with the actual requirements of the district as shown by its total metered use and a reasonable allowance for its resident population, and in this way a valuable result is reached. It often happens in such cases that a large area is shown to use but a normal quantity, considering its population, and that the night flow is not greater than it should reasonably be. This fact, once established, makes further work in that district unnecessary. On the other hand, the record may reveal an abnormal flow into a district and an excessive night consumption. This indicates a section which should be subdivided and carefully investigated. Large losses through broken mains and services, and important uses that have not been fully metered and charged for, are readily determined by such a test.

Street Inspections. Taking now the districts which are evidently consuming an excess of water, especially at dead of night, the next step is that of taking records upon short lines of mains by shutting off in their order all the services supplied on the line. This process at once indicates a place where defective service pipes or imperfect fixtures are leaking. After all known services have been shut off there may still remain a flow that indicates loss from imperfect joints, a break in the main, or some unsuspected and unmetered consumer. In old works a frequent cause of leakage is found in decayed service pipes. Forgotten and disused services and mains are fruitful sources of loss. Fire-protection mains are peculiarly subject to losses through unmetered connections, which, for aught any one seems to know, have made themselves. This street inspection brings all such misfortunes to light, and its value can only be adequately understood when the cost of the water which flows away in a constant stream for a year, and year after year, is capitalized.

By using the pitometer street connection, records can be repeated at any given point, thus revealing the changes which take place from one season to another. This adds greatly to the ease with which the use of water throughout the system can be made a matter of certainty to the manager. By locating these street connections on fire-protection mains, inspections can be made from time to time which will prevent an unauthorized use

of water through surreptitious connections. As this method of inspection leaves the main unobstructed at all times, its use is not objectionable from the fire underwriters' standpoint. If one of these street connections to each mile of main is judiciously set, it will be practicable to reach every block of a pipe system so as to determine positively whether any given water gate is shut or open, and also to locate any considerable loss of water through defective mains or services, or to locate the theft of water.

By using the pitometer in a thorough and systematic way in connection with careful inspections of fixtures, any city can know where the water of its system is used and can find every source of loss. It affords a very economical and practical way of measuring the water flowing through any pipe in any street. Its cost and its ease of handling are such that even the smallest waterworks plant can afford to use it. It is peculiarly fitted for use by large cities, where every mile of the pipe system can be inspected without interference with the supply of water.

In 1881 and later, a total of 83 Deacon meters were placed on the distribution system of the Boston Water Works in the study of waste. The average cost of their installation complete was about $600 each, making the total cost of installation in the neighborhood of $50 000. It is interesting to note that 500 pitometer street connections could be placed, one to each 3 miles of the 1 500 miles of piping of 4 inches and over supplied by the Metropolitan Water Works in 1905, and 100 complete pitometers with photo-recording apparatus installed, for the same sum of $50 000. By a careful study of the successive points of distribution of the pitometers, this equipment would enable the Board to learn the exact condition, flow, waste, leaks, breaks, etc., at every point in its large distribution system, and such data could be repeated at different periods as often as desired.

The writer installed and directed the operation of a complete pitometer, with photo-recording apparatus, at Athol, Mass., during the fall of 1905, for the purpose of determining the gravity flow through two mechanical filters. During the latter period of its operation, excavations were being made for the permanent installation of a Venturi meter at the same point. The flow by pitometer gagings was testified to at the hearings before a special

commission, before any records had been taken from the Venturi, but when the Venturi records were entered in the later course of the testimony, they were found to agree very closely with the pitometer — as should always be the case when both are installed properly and operated intelligently. The pitometer was used successfully in the famous New York waste investigations of 1902 and 1903, and is in use to-day at Chicago, Philadelphia, Pittsburgh, Havana, Washington, Spokane, Minneapolis, Rochester, Syracuse, Cleveland, Watertown, N. Y., Bridgeport, New London, and other smaller cities and towns.

In preparing the above information to cover the limited time assigned to this paper, I have extracted freely from the text of the literature published by The Pitometer Company.

DISCUSSION.

MR. C. M. SAVILLE (by letter).* I think we are greatly indebted to Mr. Blake for his interesting exposition of the pitometer and its uses in connection with water-waste investigations, especially in cases where a hurried reconnoissance is to be made over a large system.

Regarding the suggestion for installing them on the Metropolitan Water Works, I would state that this system is now equipped with 55 Venturi meters, controlling all of the connections with the 18 separate cities and towns supplied from these works. From these meters an autographic record of the flow during *any* period is available and is filed for future reference. This record requires no expert knowledge of photography or manipulation in development, and the chart can be adjusted and taken off by a laborer of ordinary intelligence.

Besides the autographic record, which gives the rate of flow at any time, the Venturi register also shows on a dial, similar to that on the ordinary house meter, the total quantity in gallons actually passed. This is a great advantage over a chart record giving only rates of flow, as it requires no calculation to reduce it to the quantity actually consumed. The chart records have furnished very interesting and valuable information regarding the use of water for fires, blowing off and flushing water pipes and

* Division Engineer, Metropolitan Water Works, Boston, Mass.

sewers, and the results on small systems of the sudden opening of connections for supplying street-watering carts and locomotive tanks. Besides the above, immediate information is given of gates carelessly opened between high and low service systems, and of breaks in mains and services from which water is running away unnoticed into drains and brooks.

On the Metropolitan system these meters have been used many times to investigate waste, the method being to feed the system under inspection through the meter, noting the time of shutting section gates, cutting off certain portions of the district, and later reading the rates of flow on the meter charts at the time mentioned, the rate of decrease, or quantity used by the cut-out section, is readily obtained.

One step further in this method of waste detection would be to tap ordinary connections on either side of a section gate and lead, say, 2-inch connections into a permanent chamber. Here, by means of flanged connections, a small Venturi meter, say, 2-inch, could be inserted at any time. By closing the main gate between the connections the flow to the district under investigation could be by-passed through the small Venturi and by means of adjustable throat pieces any rate of flow per minute from 1.74 gallons or 0.23 cubic feet to 90 gallons or 12.1 cubic feet could be automatically recorded by a manometer, while street-by-street and house-to-house inspection by closing street gates and curb cocks is being done by the water works department. The great advantages of this method are:

1. Its low cost for installation, the entire first cost (and consequent ownership) being a comparatively small amount.

2. Its portability, one outfit of meter and manometer being readily transported and used in as many testing chambers as is required on the system.

3. Its autographic record, requiring no photographic manipulation, and being ready for inspection at any time without development.

4. No survey of the pipe and determination of a proper coefficient being necessary.

5. Its simplicity of operation, lending itself readily to operation by local departments.

MR. BLAKE (*by letter*). Mr. Saville's instructive discussion has been read with much interest. It was not intended to suggest that pitometers should now be installed on the Metropolitan system, but to show what might be accomplished by their use with an investment equal to that made with Deacon meters in 1881 and later. The comparison showed the great advantages of the pitometer in point of information obtainable for a given investment.

In regard to the expert knowledge of photography which Mr. Saville thinks is required, the writer would have endeavored to make this matter, as well as several other details, clearer had time permitted. The sensitized Velox paper can be purchased at any photographic supply store, cut into the exact size desired. It must be placed on the drum in a dark room or corner, and protected from the light until in place on the drum above the clockwork. When the record is completed, which may cover twelve, twenty-four, or forty-eight hours, the Velox paper is removed, and rolled in a small tin case. Tubes of developer and acid hypo for fixing solution can be bought cheaply at almost any stationery store. Fresh water is all that is required in addition, and the simple directions show the process plainly. Photography has become so common with even young boys and girls that it can hardly be said to require expert knowledge as demanded in the development of pitometer diagrams. A laborer of ordinary intelligence can put on and remove the Velox sheets, and, if desired, they can be collected once a day and developed at the office, where, with scarcely an exception, some assistant is found well versed in photography.

In regard to the Venturi dial, referred to by Mr. Saville, which shows at a glance the gallons passing at any moment, a pitometer scale is quickly made from the tables to suit any traverse coefficient and any size of pipe, and this scale, with its zero placed at the zero line of the liquid in the U-tube, enables the observer to note the exact number of gallons passing at any moment. Furthermore, notches in the slit through which the light passes on its way to the paper are so located that they produce horizontal rulings upon the record corresponding to the calibrated deflections, and after being developed, the discharge in gallons

for the given traverse coefficient and pipe size is readily entered for each line of the record, making the record self-reading without calculation or scaling, except for intermediate points.

In the investigation of waste by the pitometer, any main can be tapped anywhere, except at or very near bends, branches, etc., without by-passing the entire supply or any part of it through a neck or other reduced section, and, of course, complete inspections can be made by shutting section gates, curb cocks, etc. Also changes in the rate of flow, due to use of water for fires, blowing off and flushing water pipes and sewers, the sudden opening or closing of gates, breaks in mains and services, etc., are faithfully recorded on the photometric diagram, not at ten-minute intervals, but continuously.

Mr. Saville suggests the use of a 2-inch Venturi meter with adjustable throat pieces in waste detection. He states that to do this would require a tap on each side of a section gate, 2-inch connections, and a permanent chamber.

Compare with this a single 1-inch corporation cock tapped into the main, a simple and inexpensive pitometer street connection placed in position, and the whole surrounded by a piece of 6-inch or 8-inch pipe running up to the surface and having an ordinary cap such as is used for curb cocks. There is no by-passing, no by-pass valves, no permanent chamber large enough for a man to work in. The comparison seems to show that for the particular field of waste detection the pitometer is preëminently fitted above all other types of meter, and is therefore destined to have a very wide use in the future, in view of the fact that every year cities and towns are made to realize that consumption must be minimized and unnecessary waste stopped. The pitometer reveals in part the actual interior condition of the pipe and measures the flow as it actually takes place in the pipe day by day.

The writer has been informed that the cost of installation of the 55 Venturi meters on the Metropolitan system was in the neighborhood of $90 000. The cost of an equal number of complete pitometers would probably not exceed $20 000. Making the same comparison as used in reference to the Deacon meters, for an equal investment of $90 000, 1 500 pitometer street connections could be placed, one on each mile of the 1 500 miles

of piping of 4 inches and over in diameter, supplied by the Metropolitan Water Works in 1905, and 150 complete pitometers installed, or one to each ten miles of piping. Thus continuous records could be taken simultaneously at nearly three times as many points as is possible with the Venturi meters now in use, and then the pitometers could be moved to other 150 points, and so on, until the day and night flow on each mile of the system had been recorded. The great increase in information thus available is obvious; and although it doubtless would not be desirable to go into the matter so minutely on the Metropolitan system, the above figures are intended to show what might be accomplished by the use of pitometers with an investment equal to that made in the case of the 55 Venturi meters.

MR. GEORGE W. BATCHELDER.* We used the pitometer in the fall of 1903 with most satisfatory results. I do not remember having any difficulty with it, and do not think it requires any expert knowledge to operate it.

We found some very startling results on some of our fire pipes, which results were afterwards practically verified by the readings of meters placed on the pipes.

The instrument appeals to us as practical and easy of operation, so much so that we shall undoubtedly order one very shortly.

* Water Commissioner, Worcester, Mass.

WATER SUPPLY, TYPHOID FEVER, DIARRHEAL DISEASES, AND INFANT MORTALITY AT BURLINGTON, VT., 1879 TO 1905, INCLUSIVE.

BY M. N. BAKER, PRESIDENT OF THE BOARD OF HEALTH, MONTCLAIR, N. J., AND ASSOCIATE EDITOR OF "ENGINEERING NEWS."

[*Read March 14, 1906.*]

The water supply of Burlington, Vt., affords an exceptional opportunity to study the relations between water supply and disease, and to extend such studies so that in addition to typhoid fever they will include both diarrheal diseases and infant mortality. This opportunity is due to the fact that Burlington draws its water supply and discharges its sewage alike into Lake Champlain, without purification in either case, and to the further fact that its vital statistics, while not wholly satisfactory, have for a long period of years been superior to those of most cities. The study is rendered doubly interesting and significant because two increases in the distance between the water intake and the main sewage outlet, making a final distance apart of some three miles, as compared with a half mile originally, appear to have failed to protect the water supply from the constantly increasing discharge of sewage into the lake, which latter has been augmented of late by the sewage of other localities than Burlington.

My first acquaintance with the water supply at Burlington was in the fall of 1882, when upon entering the University of Vermont I received the warning customarily given to students, to drink sparingly of the lake water until accustomed to it, lest it should give rise to diarrheal trouble. During and subsequent to my course at the university, I followed with interest the local contentions over the relation between the water supply of the city and typhoid fever, diarrhea, and dysentery, which many believed were unduly prevalent in Burlington.

In common with others who gave attention to the subject, I thought that the 2¼-mile extension to the water-works intake

made in 1894, which had long been advocated, would secure to Burlington the purity of its water supply for many years to come. At the annual convention of the New England Water Works Association held at Burlington in September, 1895, I listened with great interest to the paper on the history of the Burlington water works and the account of the construction of the intake extension, by my former classmate at the University of Vermont, Mr. F. H. Crandall, then and until recently superintendent of the Burlington water works. At the same convention I heard with much pleasure and profit the notable paper by Prof. William T. Sedgwick, now president of this Association, "On the Sanitary Condition, Past and Present, of the Water Supply of Burlington, Vt." (See JOURNAL OF THE NEW ENGLAND WATER WORKS ASSOCIATION, Vol. X, pp. 150-183, March, 1896, for both these papers.) After the completion of the intake and the presentation of the two papers just named, with their evidently conclusive testimony on the existing and probable future water supply of Burlington, the controversial aspects of the subject passed out of my mind until the publication in 1905 of Mr. M. O. Leighton's "Preliminary Report on the Pollution of Lake Champlain" (Water Supply and Irrigation Paper No. 21, United States Geological Survey). In this report Mr. Leighton considered at some length the history and character of the water supply of Burlington, and included many analyses of samples of water collected from the lake. On reading this report I was surprised to learn that Mr. Leighton's studies, combined with analyses made by the Vermont State Laboratory of Hygiene, at Burlington, indicated that the water supply of that city was again in a dangerous condition. About this time the Vermont State Board of Health issued an order instructing Burlington to improve the character of its water supply. The city authorities appointed a special committee to investigate and report on the subject. The membership of this committee included Dr. John B. Wheeler, chairman, and Dr. F. E. Clark, secretary, both former health officers of the city, and Mr. F. O. Sinclair, M. Am. Soc. C. E., then recently appointed superintendent of water works. In June, 1905, I was requested by the committee to report on the best means of improving the supply. My report was sub-

mitted in the following August. Its conclusions, in brief, were that the statistics of typhoid fever and diarrheal diseases, together with the analyses of the water supply, indicated that some change in the water supply was necessary, and that in view of the abundant supply afforded by the lake and the fact that the works were designed to draw thereupon, it was advisable to continue the supply from that source and to purify it by means of slow sand filtration. Subsequently the special committee embodied my report in one made by it to the city council. In general, my recommendations were indorsed, with the exception that it was not considered necessary to cover the storage reservoirs on the hill, and that the filter plant should be located at these reservoirs instead of at the lake, as suggested by me. By locating the filters on the hill, the necessity of low-lift pumps would be obviated, and by constructing a new force main from the pumping station to the filters, it would be possible to supply a considerable amount of unfiltered water in the heart of the business district for both fire protection and elevator service. The existing force main, it may be explained, serves as a distributer to branch mains along its course; that is, the system is by pumping through the distributing system to the reservoirs, the latter serving to make up any deficiency and to supply the city at any time when the pumps are closed down. Reference to other features of these reports will be made later on.

In view of the detailed information regarding the Burlington water supply already available in the papers by Professor Sedgwick and Mr. Crandall, as printed in the JOURNAL, and in Mr. Leighton's report, it seems unnecessary to go over the subject in detail. A few facts, however, may be drawn from each one of the papers named. These facts, combined with other information, having been given, I shall address myself to the presentation and discussion of those portions of the vital statistics of Burlington which bear particularly on the subject in hand.

On October 1, 1866, the city of Burlington took possession by purchase of the property of the Burlington Aqueduct Company. This company was then supplying water for domestic purposes only, by gravity, from springs located near a 75 000-gallon underground reservoir. On taking possession of the works, the city

installed a pump having a capacity of 63 000 gallons per day, and began pumping the water from the lake to augment the supply of 5 000 to 15 000 gallons daily, delivered through some 200 service connections. On December 25, 1867, the city began the use of a new water-works system which it had built for drawing water from the lake. The intake was only a short distance from the pumping station, which was located on the lake front. This intake continued in use until the completion, in 1894, of the 2¼-mile intake extension already mentioned. One or more sewers seem to have been in use prior to 1867, but there appears to have been no sewerage system until 1875. Up to 1885 the main outlet sewer discharged at the dock line about a half mile south of the water intake. In that year an intercepting sewer appears to have been constructed to convey the sewage to a point farther south, the new outlet being about three fourths of a mile from the water-works intake. Storm overflows, it appears, have continued in use since this extension. The water intake extension of 1894 separated the water intake and outlet sewer by about three miles, but at the same time the outlet sewer, which had previously discharged into quiet water, serving as a settling basin, was extended to the dock line, and since then it has discharged into the open lake. The effect of the basin named was to remove, presumably, a considerable part of the dangerous polluting matter from the sewage before the latter reached the main lake. With the extension of the outlet to the dock line the full volume of sewage was subject to the lake currents, as exercised within the line of the breakwater, which parallels the water front for about a mile. The normal lake current is, of course, to the north, but this current is gentle, and within the bay and breakwater it is not only less pronounced than without, but it is also liable to reversal, at least at the surface, by adverse winds.

The new water intake was composed of 24-inch cast-iron pipe, laid in 75-foot sections, with Falcon ball joints between sections. The 75-foot sections were joined by leading in the usual way, the joints being of the bell-and-spigot type. This jointing was done on shore, and each 75-foot section was tested under hydraulic pressure. The sections were then moved out by scows,

sunk, and the ball-and-socket joints, which, of course, had been applied beforehand, were connected under water by a diver. The Falcon joints are described by Mr. Crandall as follows:

"This joint is made of a ball cast of such diameter, larger than the pipe on which it is to be used, as to admit the desired deflection to be obtained without obstructing the waterway, and a flanged spherical ring of about three-eighths inch greater radius than the ball and of such width that the ball cannot pass through it. These two parts are leaded together and attached to one end and a flanged bell, planed so as to make a tight thimble for the ring which is attached to the other end of a section to be laid.

"The flanged joint is made by a diver with the aid of a thin rubber packing, and after it has been for a short time in our lake water the oxidation which takes place on the planed surface of the ring and thimble makes it entirely watertight. In a case like that of our intake, where there is no current of constant and high velocity to keep open and increase the size of leaks induced by changes of temperature or settlement, it may safely be expected that all small holes will be closed by oxidation."

Mr. Crandall stated in his paper that the bottom of the lake, on which the pipe rests,

"is nearly level, but there are two summits in the distance, and on those summits were placed brass ferrules with two one-eighth-inch holes bored in each ferrule. Before these holes were opened, the water was let on at a pressure of about 20 pounds, and we noted the amount of leakage, and the same was done afterwards, showing the leakage occasioned by the holes. This was done each time that air vents were placed, and when the test was finally made, the pressure which they were subjected to was from 12 to 15 pounds, and the leakage, aside from that through the air vents, was about 100 gallons per hour in the entire length of about 3 miles."

Attention is called to these descriptions of the methods employed in making and testing the lead joints on shore, connecting the sections under water, and testing the intake conduit after it was laid. The question naturally arises whether all the joints made under water rusted to tightness, as Mr. Crandall expected would be the case.

The provision of a gate at each extremity of the intake conduit, that is to say, at the pump well and at the upturned outer

end of the intake, made it possible to retest the whole intake at any time after it was put in use. No reference to such tests has been found by me in the annual reports of the Water Department; and although the first recommendation of my report, dated August 30, 1905, was that such tests be made, none had been undertaken up to March 1, 1906.

It should be noted that the intake conduit was laid in water ranging from some 14 to 50 feet in depth, and terminated in water some 30 feet deep, but with a strainer capped, upturned end, the upper portion of the perforated cap being 14 feet below ordinary low water in the lake. The successive depths at which the intake was laid from the pumping station outward, at approximately equal intervals, were as follows: 12 feet (near the shore), 24, 38, 46, 48, 46, 46, 28, 45, 50, 44, 29, 31 (and 14 at the strainer, at stated above).

Professor Sedgwick's paper contains a number of very interesting extracts from the reports of successive health officers, beginning as early as 1870, calling attention almost without exception to the desirability of extending the old intake at once. The two exceptions were to the effect that the allegations against the character of the city water supply were apparently unfounded. In the year 1870, Professor Sedgwick states, there were 5 deaths in Burlington from dysentery and 3 from diarrhea, and in 1871 there were 10 deaths from dysentery, according to the city reports. These figures certainly emphasize the need, even as early as 1870, for the extension of the intake, which was deferred, as already indicated, until 1894. Professor Sedgwick included in his paper the substance of a report made by him to the city of Burlington in 1892. In that report he reviewed briefly the typhoid statistics of the city for some years previous. The typhoid mortality, together with the deaths from diarrhea and dysentery, he did not consider alarming; nevertheless, the body of the statistical evidence available, combined with the opinions of successive health officers and practicing physicians, and the known fact that sewage was discharged into the lake so near the intake, all pointed, he concluded, to the need of an improved water supply, which it then appeared could best be secured by extending the intake. Such an extension seemed all the more desirable at that time be-

cause Mr. F. P. Stearns, M. Am. Soc. C. E., had just been called in to advise on the abolition of the nuisance caused at low water by the discharge of sewage into the basin at the mouth of the outlet sewer. Quite recently the lake had been unusually low and the exposure of the sludge-covered mud flats in the basin had resulted in an almost intolerable stench. Mr. Stearns advised that the outlet sewer be extended across the basin to the lake front. This, as has already been mentioned, was completed the same year as was the extension of the water intake.

Between the date of his report and of his paper read in 1895, Professor Sedgwick made numerous bacterial analyses of water from the Burlington supply, and took pains to secure the opinion of some of the physicians of Burlington as to the benefits derived from the extension of the water-works intake. The concluding paragraphs of Professor Sedgwick's paper of 1895 are well worthy of quotation here:

"In view of all the evidence at hand — statistical, bacteriological, chemical, and medical — I think we may safely conclude that the sanitary condition of the water supply of Burlington is now most excellent. If, however, in the future, Burlington grows extensively and becomes a much larger city, it will probably become necessary here, as in most large cities, to face once more the question of a pure water supply. Special pains must also be taken to see to it that the intake pipe is kept intact and free from leakage. The unfortunate experiences of Toronto and of Buffalo with broken intake pipes afford ample warnings in this direction.

"This is the first case within my own experience, now somewhat extensive, in which epidemic diarrhea in a mild form has prevailed in a community for many years, having its etiology in the consumption of impure water, as has been proved by its apparent total disappearance on a change in the source of supply. The importance of the case in the history of water-borne diseases is manifest. It was complicated by the fact that typhoid fever, which is usually taken as a measure of the sanitary condition of a community, was here ordinarily by no means excessive, and that its occasional prevalence might easily have been due to some other cause than polluted water. The fact seems to be, however, that it was in truth really due to impure water, inasmuch as since the extension of the intake pipe in 1894, typhoid fever has practically disappeared.

"It would seem fair to conclude, from the moderate occurrence

of typhoid fever, while diarrhea abounded, that germs of the latter disease, more hardy than those of the former, were frequently able to survive a journey from the sewer outfall to the water intake, while those of typhoid fever, if present, usually perished. In future, sanitarians will not be able by the test of typhoid fever alone to show that a water supply is above suspicion. A mild form of diarrhea caused by polluted water may apparently prevail even in the absence of any constant or considerable excess of typhoid fever."

At the conclusion of the first of the paragraphs just quoted, it will be noted that Professor Sedgwick suggested two possible future contingencies which might demand renewed efforts to secure or maintain a pure water supply: (1) A large increase in the population of Burlington, which has scarcely taken place yet, since the population now appears to be only some 25 per cent. more than it was then; and (2) leaks in the long intake pipe, on which possibility there seems to be no specific information available up to the present time. But in some respects even more impressive than these two suggestions are the remarks in the last paragraph of the quotation, on the relation between a polluted water supply and an excessive amount of diarrhea. This summary of a most significant feature of the sanitary history of the Burlington water supply, and particularly the last two sentences of the paragraph, mark a new epoch, as I believe, in the study of the relations between water supply and disease. The impression made upon me by these remarks, taken in connection with my early knowledge of the effect of the Burlington water supply upon new students at the University of Vermont, and my long-time conviction that sewage pollution did cause other intestinal disturbances than typhoid fever, determined me, on taking up the investigation of the Burlington water supply last year, to attempt a more detailed study of both the typhoid and diarrheal mortality of Burlington than had ever been made before. This determination was strengthened after some study of the Burlington typhoid had confirmed the opinion, by no means held by me alone, that much of the disease had been concealed, particularly in earlier years, by reporting deaths that were actually from typhoid fever as some one of the now well-recognized class of diarrheal diseases.

Never was the need of combining the study of vital statistics with that of chemical and bacterial analysis of a public water supply better illustrated than by this Burlington case. The futility of water analyses alone is well put by Mr. Leighton in his paper on the "Pollution of Lake Champlain." After reviewing the sanitary history of the Burlington water supply, Mr. Leighton says:

"One of the most striking features in connection with Burlington pollution brought out by the report of Professor Sedgwick is the apparently enormous power possessed by the lake to assimilate large quantities of contaminating matter and to conceal almost every chemical as well as biological evidence of the presence of pollution."

Mr. Leighton also raised the question whether, in the twelve years since Professor Sedgwick's report, the lake, or rather Burlington Bay, had received so much pollution that it had lost a part of its power of assimilating impurities. He then presented a number of series of analyses of samples of water, collected in the latter part of 1904, the analyses and text being accompanied with charts showing the sampling points. The object of these analyses was to show the range and strength of sewage pollution, both that due to the sewers of Burlington, discharging some three miles to the south of the water intake, and that due to the sewage of Fort Ethan Allen and the village of Winooski, discharged by way of the Winooski River at a point in the lake about three and one-half miles to the north of the intake, Winooski being nearly ten miles, by the river, from the river mouth, and the fort some miles above Winooski. (See discussion of the Winooski River influence, further on.) Much of Mr. Leighton's analytical work was admittedly tentative, some of the results were conflicting, and most of the samples from given points were of a single date only, but the analyses as a whole were instructive and indicated sewage pollution over a large area, including most of the area traversed by the intake conduit and also the area between the intake mouth and the mouth of the Winooski River. Such evidence as was secured rested chiefly on the bacterial rather than the chemical analyses. Most of the counts of total bacteria were not high, all things considered, but the colon bacillus was indi-

cated by many of the samples. Mr. Leighton points out, however, that the coli tests, as made for him at the Vermont State Laboratory of Hygiene, were presumptive, instead of direct, but nevertheless he considered that such of these as gave positive results were undoubted evidence of intestinal bacteria. He held, in conclusion, that the Burlington water supply was undoubtedly polluted by sewage, but that in view of the illusive character of the sewage contamination, so far as analytical determinations are concerned, the record of intestinal diseases in Burlington was the best means of showing "the unfavorable effects of Burlington sewage" on the water supply of the city.

In none of the published studies of the Burlington water supply, and in none of the annual reports of the various health officers of Burlington, do there appear (with one exception) detailed typhoid statistics for a long series of years; and nowhere have there been published detailed statistics of diarrheal mortality. In Professor Sedgwick's paper, already mentioned, the total mortality, typhoid mortality, and percentage of the latter to the former, were given for the years 1870 to 1895, inclusive, and some figures were also given of the typhoid rate per 100 000 for selected years and for groups of years.

Although my first negotiations with the special water supply committee at Burlington, in June, 1905, assumed that both the pollution of the water supply and the necessity for a change of some kind were proven, yet it was finally deemed advisable to show beyond all question, in connection with recommendations for improving the supply, why an improvement, and that immediately, was imperative. I therefore devoted practically all of my spare evenings, for a number of weeks in the summer of 1905 (largely as a labor of love), to an exhaustive study of the Burlington city reports and a compilation and analysis of such of the vital statistics of Burlington as I thought bore upon the subject in hand. I had in my possession the annual reports of the city from the fourth to the fortieth (1868–69 to 1904, inclusive), but inasmuch as the registration of vital statistics did not begin at Burlington until well into the year 1878, I started my figures with the calendar year 1879. Prior to 1878 and well into that year, the vital statistics of Burlington were based upon a canvass

of the city made in January of each year. As may be seen from Professor Sedgwick's paper (page 175), no deaths from typhoid were reported in Burlington for the three years 1873 to 1875, inclusive. In view of the fact that this statistical work of mine, as already stated, was largely a labor of love, and that my report to the special water commission has recently been published minus all the statistical tables (Burlington City Report for 1905), perhaps I need not apologize for presenting the tables complete herewith, with the corresponding figures for the full year 1905 added thereto. I shall also take the liberty of repeating, without quotation marks, considerable portions of my comments on the tables, as made in the appendix to my report, but with some alterations in form and with some additional reflections.

For a number of years, beginning with 1879, the vital statistics of Burlington probably surpassed in completeness and classification those of most cities of its size. There is reason for believing that they are still more than usually complete and well summarized, but it seems a pity that Burlington has not yet adopted the United States census classification of the causes of deaths and thus put its mortality records on a comparative basis with those of other cities. However, most of the essential facts appear to have been given for some years past, rendering a reclassification no serious matter. The footnotes to some of the accompanying tables will show the new classifications and combinations made in connection with deaths from typhoid fever and from diarrheal diseases.

Table No. 1 shows by years, from 1879 to 1905, inclusive, or for twenty-seven years, the midyear populations, total deaths, and deaths per 1 000 population, and also for typhoid fever, diarrheal diseases, and children under five years of age, the number of deaths and the death rates per 100 000 population and the percentage which the deaths from each of these diseases bears to the deaths from all causes. For typhoid fever alone an attempt has been made to include the yearly number of cases, but it was not until 1898 that the cases began to be reported with anything like apparent completeness, the deaths actually equaling or exceeding the cases in the earlier years and the cases not being reported at all in years as recent as 1889 and 1890. As may be

seen, this table shows great fluctuations in all mortality particulars except the death-rate from all causes, which has been fairly constant, and that at a high rate for a city under such favorable natural conditions as are enjoyed at Burlington. Particular attention is called to the fact that although the typhoid deaths for the year 1905 are low, only 15 per 100 000 population, yet the number of reported cases (32) is high, and so are the total deaths and the deaths from diarrheal diseases and of children under five years of age.

Before proceeding further, I wish to explain why I have included deaths from diarrheal diseases in my study and also deaths of children under five years of age. It has been usual, heretofore, to stop short with a consideration of typhoid fever as an index of water pollution and a measure of the effect of such pollution on the public health. The idea has often been expressed, however, that public water supplies unquestionably affect the total death-rate otherwise than through typhoid fever. How to measure that further influence has never yet been determined, so far as I know, but it has been suggested again and again that the large class of diseases known as diarrheal have their many fatalities raised or lowered by the sanitary quality of the water supply.

Unfortunately, mere cases of diarrhea are not reported at Burlington, or, so far as I know, in any other American city. In fact, unless serious, most of them do not come to the attention of a physician. Deaths from diarrhea have not figured high at Burlington, at least not as indicated by the published vital statistics. This may be due to difficult, even if not to faulty, classification and to variations in the classification of reporting physicians from year to year. To have some broader and more stable basis of comparison than is afforded by diarrhea, or even diarrhea and dysentery together, I have included in my Table No. 1 the whole class of diarrheal diseases, as used by the United States Census Bureau. The details on which depend the total for diarrheal diseases shown in Table No. 1 are given in Table No. 2. I have been compelled to add two columns to the list of headings taken from the census, namely, gastro-enteritis and ulceration of the bowels. If I may venture an opinion on such a subject I would sug-

gest that some of the entries under these two heads, under more recent diagnosis, would have swelled the typhoid fever totals, as given in Table No. 1, for the corresponding years. The same is doubtless true of some of the other entries in Table No. 2. In fact, I think this table as a whole is a strong argument for an entire change of base in the study of polluted water supplies and the public health, particularly in the case of the older records. But to hold more specifically to the case of Burlington, I think no impartial competent judge who is or could become familiar with the past disputes at Burlington over the relation between the public water supply and typhoid fever could study the detailed figures of typhoid fever and of diarrheal diseases brought together in this report without being convinced that Burlington has had far more typhoid fever than was ever reported as such, and that there was far more relation between the water supply and diarrheal diseases than has generally been supposed.

The cholera infantum column (Table No. 2) may be consulted with possible profit in connection with both the total deaths from diarrhea and the infant mortality (the latter given in Table No. 1). Some may be inclined to exclude cholera infantum from diarrheal diseases as related to public water supplies, and others to connect many of the cases with impure water. The figures will be interesting to either school of opinion.

The high infant (persons under five) mortality, whether or not attributed in part to the water supply, certainly demands attention, particularly as it shows comparatively little improvement of late.

If it be assumed, as I have for some years past, that a persistent typhoid death-rate of 20 or more per 100 000 population is a reflection on a public water supply, it will be seen from Table No. 1 that the Burlington supply has been subject to condemnation through the greater part of the twenty-seven years covered by the table, with no allowances whatever for the deficiencies in the statistics. The rate has ranged from 6 to 79 per 100 000 and in sixteen of the twenty-seven years has exceeded 27 per 100 000.

In his report to the city of Burlington, made in 1892, Professor Sedgwick referred to an average typhoid rate of 35.7 per 100 000 for a term of years as not high, compared with other cities having

water supplies of good reputation. For that date, and coming at about the time of the notable studies of typhoid fever and water supply at Chicago, Philadelphia, and elsewhere, made by Professor Sedgwick and Mr. Allen Hazen, perhaps an average typhoid death-rate of 35 per 100 000 might not be considered excessive, but I think few persons to-day will fail to agree that so high a rate is a cause for deep concern, particularly if it is suspected that all typhoid deaths are not reported as such, and if it is found that diarrheal and infantile mortalities are high. In no less than 8 of the 27 years between 1879 and 1905, inclusive, was the typhoid death-rate at Burlington above 35 per 100 000, while for these eight years the combined mortality from typhoid fever, diarrhea, and infantile diseases ranged from 46 to 68 per cent. of the deaths from all causes. For convenience of comparison I have brought together in Table 2–A the deaths per 100 000 from all causes and from the three causes named, for the eight years in question; and to emphasize the bad general showing of 1905, notwithstanding its low typhoid mortality of 15 per 100 000, I have added the corresponding figures for that year.

Having examined the yearly figures and their vagaries in some detail, it may lessen the resulting confusion if we smooth out the extremes by considering averages for larger periods. In order to get equal periods for comparison, and also to put by itself the year in which was made the 2¼-mile extension of the water intake, the averages have been cast in the three five-year groups preceding and two similar groups following the year 1894. For our purposes the most significant columns in Table No. 3 are those relating to typhoid fever. The deaths per 100 000 from this disease rose from 27 for the five years ending with 1883 to 42 for the next five years and 44 for the years 1889–93, inclusive. The new intake was put in use some time in August, 1894, and for that calendar year the rate fell to 12. In 1895 (Table No. 1) it dropped to 6 per 100 000, but for the five years ending with 1899 it was 16. During the period 1900–4 the rate rose to an average of 25, or nearly equal to the rate for 1879–83. In 1905 it fell to 15, but, as already stated, the total number of typhoid cases and the other statistics in Table No. 1 are far from reassuring.

The diarrheal diseases, if we take both the deaths per 100 000

and the percentages of deaths from all causes into account, show an increase before and a decrease upon and after the intake extension. Deaths under five years increased in the second five-year period, dropped in the third period and fell still further in 1894; since 1894 they have risen and fallen, successively, standing for 1900–4 quite near the rate figures for 1889-93. For 1905 the mortality from diarrheal diseases was higher than it had been since 1897.

By way of comparison, it may be noted that for the registration cities of the United States in the year 1900. according to the Twelfth United States Census, the diarrheal diseases gave an average of 156.7 deaths per 100 000; the range was from 191.7 for Rhode Island to 117.6 for Michigan cities. The corresponding rural rates were 97.2 for all the registration states; 172 for Rhode Island and 65.6 for Vermont. At Burlington the diarrheal death-rate in 1900 was 182; in 1904, 168; and in 1905 it rose to 232.

So many other factors than water supply enter into both the diarrheal and the under-five-year rates, and particularly into the latter, that undue weight should not be given those rates, but on the whole there is reason for congratulation in their general continued downward tendency and also in the like progress of the general mortality or deaths from all causes. But these several declines make all the more striking the recent steady increase in the typhoid deaths per 100 000. Turning from the five-year periods back to the yearly figures, we find that the typhoid death-rate per 100 000 of 36 in 1904 and of 38 in 1900 have not been exceeded in any single year since the rates of 63 and 45 in 1893 and 1892, respectively.

It is only fair to the water supply to say that milk, oysters, and some other foods liable to sewage pollution may spread typhoid; and that the common house fly is now believed to be a means of infecting food, in sections where privies exist and are accessible to flies. It should also be noted that with populations no larger and typhoid deaths no more numerous than found in Burlington, a slight addition to or decrease in the number of deaths from typhoid makes large variations in yearly rates and in percentages of typhoid to total deaths. Contaminated milk from some dairy or a shipment to Burlington of contaminated

oysters might not cause an epidemic of such magnitude as to lead to a discovery of the real cause of the trouble, but by adding five typhoid deaths to the list might greatly increase the typhoid death-rate for a given year. Another possible factor in the typhoid fluctuations may be patients from outside Burlington admitted to the Mary Fletcher Hospital. It may be noted here that the hospital sewage for some years was discharged into the Winooski River, but about 1892 it was diverted into the lake, thus possibly intensifying the danger of typhoid infection from the water supply. The mention of the hospital also suggests two other institutions which in times past, and I presume at the present time, add an element to the population which may have a marked effect on the returns of deaths from both diarrheal diseases and children under five years of age. I refer to the two children's homes in the city, which at times have added materially to the infant population by receiving children from other parts of Vermont, and therefore may explain, in part, the high infant and diarrheal disease mortality. It is not probable that milk and other food infection combined with the hospital and the institutions for children would fully account for the unsatisfactory typhoid and other vital statistics, though possibly they would lessen somewhat the reflections cast on the water supply.

Unfortunately, the annual reports of the various health officers of Burlington throw no light upon any of the questions raised in the last few paragraphs. They show no investigation whatever of individual cases of and deaths from typhoid fever for the purpose of tracing and removing the source of infection. They give evidence of much concern regarding the public water supply, but of no attempt to settle its actual or assumed connection with typhoid fever, further than through water analyses. I am the more surprised at this because of the evident care and thought given to some phases of health work in Burlington during the past thirty-five years.

The lack or apparent lack of all evidence of the class just named seems to force us back upon deductions already drawn from the data thus far presented, and upon some further details of the same general character, namely, the monthly distribution of deaths from typhoid fever and some digests of water analyses.

Table No. 4 shows the monthly distribution of typhoid deaths from 1879 to 1905, inclusive. The total typhoid deaths for each month during the entire period are also given, and have been rearranged from greatest to least in one of the footnotes to the table. The combined Februarys have 19 of the 120 deaths occurring during the twenty-seven years, and the combined January–March quarters have 44 of the 120 deaths. The lowest combined quarterly showing is 19 typhoid deaths for April–June. The indications are that the ice-covering of the lake is conducive to a high typhoid death-rate. Unfortunately, the returns of cases are too incomplete, particularly in the earlier years, to be of much value.

A study of the analyses made at the State Laboratory of Hygiene, and published in the yearly report of the Water Department, indicates that since 1899, when analyses were begun, the water has frequently been of a decidedly suspicious character. Table No. 5 presents averages of some of the leading features of these analyses. The chemical figures for 1899 and 1900 are notably higher and the bacterial figures decidedly lower than those for later years, except that the total bacterial counts for 1905 averaged the lowest of those for any year shown in the table. Altogether the analyses show variations not easily explained, particularly when taken in conjunction with the vital statistics. On the face of the figures the average analytical results have improved or remained about stationary, save for a slight increase in total bacteria up to and including 1904, a marked fall (to 172 per cubic centimeter) in 1905, and also a recent increase in the relative number of samples showing *B. coli communis*, or the organism common to sewage.

A much more extended series of *B. coli* determinations than those published in the annual reports was concluded at the State Laboratory of Hygiene in January, 1905. A summary of these daily examinations is given herewith, as Table No. 6. It will be seen that of 337 daily samples no less than 147, or 44 per cent., showed *B. coli* present; also that the percentages by months ranged from 60 in December and 57 in January to 25 in July. Judged by generally accepted standards, these daily coli tests afford the most direct and damaging of all the recent testimony against the water supply.

When the intake was extended it was supposed that danger from sewage contamination was removed for many years to come. To account for its so speedy recurrence is not easy, in view of all the circumstances thus far presented, unless one accepts either one or the other of two possibilities: increase in volume of sewage resulting in a wider range of sewage influence, or else leaks in the intake.

As to the volume of sewage now reaching the lake and the probability of its being carried to the mouth of the intake, the following is interesting, even though not conclusive, so far as actual effects are concerned: The sewer outfall is about three miles from the intake. Mr. Leighton's studies led him to conclude that the sewage influences are widely extended and sometimes reach the intake. He gave no little weight to the pollution of the lake at the intake by the sewage brought down in the Winooski River. Unquestionably this is a possible source of danger, but it appears to be far more remote than the danger from the sewage which Burlington discharges directly into the lake. This is evident on considering that from the intake to the mouth of the Winooski is 3½ miles; from the mouth of the river to the poor-farm, 25 000 feet, and to the falls of the Winooski 25 000 feet more. For these distances I am indebted to Mr. F. O. Sinclair, superintendent of water works at Burlington, who also informs me that a small amount of crude sewage is discharged into the river from the poor-farm buildings; that a small part of the population of Burlington is served by a sewer which discharges into the river below the falls; and that Winooski is well provided with sewers, all of which discharge at or near the Falls. Winooski had a population of 3 659 in 1900. Above Winooski, Fort Ethan Allen, I am informed, discharges the sewage of 1 000 or more men into the river, and above that there can be no large amount of sewage pollution until Montpelier is reached, and the direct pollution there, I should suppose, is not large.

According to Mr. Leighton's paper, the Winooski River has a total drainage area of 395 square miles. As nearly all the sewage reaches the river at and above Winooski, it will be seen that before reaching the intake it must pass nearly ten miles through a relatively large, sluggish, and tortuous stream, and then 3½ miles

across the lake, or more than 13 miles in all. Sedimentation and other natural causes in the river and the same factors in the lake, generally acting in the latter case over a wide area and assisted by a still greater dilution, must reduce to a very low figure the usual number of sewage bacteria reaching the intake by way of the river. Among these it is probable, though not certain, that the typhoid bacillus would seldom be found, as water is far from being its natural habitat and it is less hardy in water than *B. coli* and other forms.

The poor-farm sewage stands much more chance than does any other conveyed by the river of reaching the intake in a dangerous condition, since it is so much nearer. Perhaps more serious still, though of this I have little information, is the rendering works on or near the lake shore opposite the intake. Dejecta from cases of typhoid fever at either the poor-farm or the rendering works might be cause for uneasiness if they were allowed to get into the river or lake without thorough disinfection. The populations involved at these points, however, are small.

Reverting now to the sewage of Burlington, as discharged directly into the lake, some idea of what this amounts to can be gained from Table No. 7, which shows by five-year intervals the lengths of all sewers within the city as compared with the mileage of streets and of water mains. It was not until 1895 that a third of the street mileage was provided with sewers, and at the close of 1905 only half of the street mileage had sewers. The water mains have always covered a much larger percentage of the street lengths than have the sewers. Since 1895 the sewer mileage has increased by half, and presumably a far larger percentage of the population is sewered than is indicated by the relation between sewer and street mileage. Lack of sewer connection records in early years makes a direct comparison of sewer and water connections impossible. All the indications are that the percentage of the total population connected with the sewers has increased much faster of late than the total population itself, and that this will be the rule for some years to come. This fact may have no little bearing upon the apparently more rapid increase of pollution of the lake by sewage than was expected when the intake was extended.

Obviously the Burlington records ought to show how many and just what houses are connected with the sewers. Such knowledge is essential to modern health-protective work. A more vital lack in the health-protective equipment of Burlington is the absence of a milk ordinance, combined with dairy inspections, dairy and milk dealer licenses, and other essentials to the full control of the sanitary condition of the milk supply of the city. A milk ordinance of June, 1901, aims to guard milk consumers against tuberculosis, the dissemination of which through milk is a mooted question, and against milk adulteration, which is largely a question of economics rather than sanitation, but leaves the people wholly unguarded against the spread of typhoid fever, scarlet fever, and diphtheria, and the aggravation if not the spread of infantile diarrheal diseases through dirty and germ-infected milk. To this negligence I attribute no small part of the excessive infant and diarrheal diseases mortality, and through these the high general death-rate as well, which latter is excessive for a city of the size, character, and natural advantages of Burlington. It is also probable that some of the typhoid fever has been due to a lack of complete sanitary supervision of the milk supply.

The foregoing paragraph completes the modified excerpts from my Burlington report. It would be highly interesting, and probably instructive, if time permitted, to extend this study in the following particulars: Typhoid records of Winooski village and of Fort Ethan Allen, and the extent of the Winooski sewerage system at various dates; out-of-town patients, total deaths, and typhoid deaths, by years, at the Mary Fletcher Hospital, and possibly the yearly number of inmates and the vital statistics of the two children's homes; and notably, as affecting the total and the infant mortality, the distribution of population of Burlington by age and nativity. It seems probable that the number of children in Burlington is unusually high in proportion to the population, owing to the presence of the two children's homes and the considerable number of French Canadians living in the city. But none or all of these further lines of investigation give promise of removing or to any great extent lessening the suspicion attaching to the water supply of the city. It is of the highest

importance that it be determined at once whether the intake conduit is leaking, and if so whether the water thus admitted is worse than that taken in at the intake mouth. Such a determination involves tests for tightness, provided for by the gates placed at each end of the conduit when it was constructed, and also a fairly extensive series of analytical tests of water taken from points over the intake mouth and at selected points over the whole length of the intake conduit.

Finally, in the light of the statistical and other evidence presented by Professor Sedgwick, Mr. Leighton, the Vermont Laboratory of Hygiene, and myself, it seems that the principle laid down by Professor Sedgwick more than ten years ago, and already once quoted in this paper, is now established beyond all question, namely: "In future, sanitarians will not be able by the test of typhoid fever alone to show that a water supply is above suspicion." The additional test suggested or implied by Professor Sedgwick was the statistics of diarrhea. It does not seem to me, however, that these additional figures alone, in the present state of vital statistics, will be adequate. I do not make so bold as to claim that the whole group of diarrheal diseases, and the infant mortality as well, are essential to the study of the relations between polluted water and disease, but I think the evidence points that way to such an extent as to demand further and broader investigation.

TABLE No. 1. — Population, Total and Typhoid Deaths, and Other Vital Statistics of Burlington, Vt., 1879 to 1905, Inclusive.

	Population.*	Total Deaths.	Deaths per 1 000.	Typhoid Fever.				Deaths from Diarrheal Diseases.			Deaths under 5 Years.		
				Cases.‡	Deaths.								
					Total	Per 100 000.	Per cent of all deaths.	Total.	Per 100 000 Population.	Per cent. of all deaths.	Total.	Per 100 000 Population.	Per cent of all deaths.
1879	11 000†	212	19.3	3	2	18	.94	25	227	11.8	91	828	43
1880	11 365	207	18.2	7	3	26	1.45	30	264	14.5	96	845	46
1881	11 690	205	17.5	3	2	17	.98	19	162	9.3	91	779	44
1882	12 010	230	19.2	6	8	67	3.48	20	166	8.7	88	732	38
1883	12 335	224	18.2	1	1	8	.45	25	200	11.2	95	772	43
1884	12 655	218	17.2	20	10	79	4.59	30	237	13.7	87	688	40
1885§	12 980	247	19.0	0	1	8	.40	24	185	8.9	119	911	48
1886	13 300	248	18.6	2	4	30	1.66	29	218	11.8	101	753	41
1887	13 625	270	19.9	10	4	30	1.48	33	243	12.2	118	868	44
1888	13 950	347	24.3	26	9	64	2.60	59	423	17.0	168	1 204	48
1889	14 270	233	16.3	No report	8	56	3.43	35	245	15.0	97	679	42
1890	14 590	288	19.7	"	4	27	1.39	49	336	17.0	135	925	47
1891	14 995	255	17.0	16	4	27	1.57	25	166	9.7	66	447	26
1892	15 400	306	19.2	27	7	45	2.27	56	363	18.3	127	825	41
1893	15 805	281	17.8	30	10	63	3.56	27	171	9.6	93	595	33
1894‖	16 210	290	17.9	4	2	12	.69	35	216	12.1	94	580	32
1895	16 615	291	17.5	15	1	6	.34	21	127	7.2	112	674	38
1896	17 020	360	21.2	6	4	24	1.11	45	265	12.3	153	893	42
1897	17 425	333	19.1	7	2	12	.60	44	254	13.2	123	706	37
1898¶	17 830	283	15.9	32	5	28	1.79	12	68	4.2	83	465	29
1899	18 235	348	19.1	33	2	11	.59	35	192	10.1	111	608	32
1900**	18 640	329	17.7	35	7	38	2.12	34	182	10.3	114	612	35
1901	19 045	326	17.2	22	5	26	1.53	34	178	10.4	123	646	38
1902	19 450	312	16.0	19	2	10	.64	25	128	.79	114	586	37
1903	19 855	379	19.0	29	3	15	.79	30	151	.79	116	584	31
1904	20 260	365	18.0	36	7	36	1.91	34	168	9.3	126	622	35
1905	20 665	434	21.0	32	3	15	.68	48	232	11.1	145	700	34

* Population for intercensal years computed by the United States Census Bureau method; that is, by arithmetic increase between censuses.

† The population decreased about 3 000 from 1870 to 1880; the 1879 population used is arbitrary.

‡ Cases of typhoid cannot be compared with deaths, since the compiler has added to the typhoid deaths given in the annual health reports all deaths reported as bilious, continued, enteric, slow and typho-malarial fever. See footnote to Table 4, Deaths from Typhoid by Months.

§ Main outlet sewer shifted to point one-half mile farther from water intake, making a total distance of about one mile, but understand that storm overflow has been in use at old outlet ever since.

‖ New intake in use " several months " during 1894, apparently beginning in August. Main outlet sewer extended in 1894 to discharge at dock line, instead of into still water, virtually a settling basin, back of dock line.

¶ Late in 1898 a reservoir of nearly 4 000 000 gallons capacity was put in use, and the old reservoir, which was in great need of cleaning, was disconnected. Not stated whether used again before 1900.

** Old reservoir cleaned, repaired, and banks raised; capacity evidently increased from about 2 350 000 to 3 000 000 gallons, making a total capacity of about 7 000 000 gallons, not including high-service tank.

TABLE No. 2. — Deaths from Diarrheal Diseases at Burlington, Vt., 1879 to 1905, Inclusive.

	Cholera Infantum.[1]	Cholera Morbus.	Colitis.	Diarrhea.*	Dysentery.*	Enteritis.	Gastro-Enteritis.	Ulceration Bowels.	Total.
1879	18	..	..	5		2	..	..	25
1880	20	..	..	7		3	..	..	30
1881	12	1	..	2		4	..	..	19
1882	7	3	1[1]	4		3	2	..	20
1883	8	..	..	5		12	..	..	25
1884	16	..	..	7		3	4	..	30
1885	13	..	..	..	1	8	2	..	24
1886	19	1	..	..	..	2	6	1	29
1887	15	4	..	..	2	4	8	..	33
1888	32	1	..	..	1	12	12	1	59
1889	13	..	9[1]	1	..	7	5	..	35
1890	26	..	6[1]	1	2	7	6	1	49
1891	14	..	3[1]	..	..	3	3	2	25
1892	37	2	..	3	..	6	7	1	56
1893	15	1	1[1]	2	1	2	5	..	27
1894	22	2	2[1]	..	1	4	3	1	35
1895	14	..	1[1]	2	2	1	1	..	21
1896	28	..	5[1]	5	2	4	1	..	45
1897	22	2	2[1]	2	1	8[2]	7	..	44
1898	3	..	..	3	1	2	2	1	12
1899	21	1	1[1]	1	..	8[3]	3	..	35
1900	20	1	2[1]	..	..	6	5	..	34
1901	21	1	3[1]	2	1	3	3	..	34
1902	17	..	1[1]	..	1	5	1	..	25
1903	17	..	3[1]	1	..	2	7	..	30
1904	19	..	5[3]	3	..	3	4	..	34
1905	17	..	4[1]	..	1	9	17	..	48

* From 1879 to 1884, inclusive, diarrhea and dysentery were not separately reported.

[1] Entero-colitis.

[2] Including one intestinal colic.

[3] Including one entero-colitis.

TABLE No. 2-A. — Deaths per 100 000 at Burlington, Vt., from All Causes, Typhoid Fever, Diarrheal Diseases and Deaths under Five Years, for those Years in which the Typhoid Death-Rate Exceeded 35 per 100 000.*

	All Causes.	Typhoid Fever.	Diarrheal Diseases.	Under Five Years.	Per Cent. Three Causes are of All Causes.
1882	1 920	67	166	732	50
1884	1 720	79	237	868	58
1888	2 430	64	423	1 204	68
1889	1 630	56	245	679	60
1892	1 920	45	363	825	65
1893	1 780	63	171	595	46
1900	1 770	38	182	612	47
1904	1 800	36	168	622	46
(1905†)	(2 100)	(15†)	(232)	(700)	(46)

* In sixteen of the twenty-seven years from 1879 to 1905, inclusive, the typhoid mortality exceeded 20 per 100 000.

† 1905 inserted for comparison.

TABLE No. 3. — Death-Rates from All Causes and from Typhoid and other Diseases by Five-Year Periods before and after Extending Burlington Water-Works Intake.

	All Causes per 1 000.	Typhoid.		Diarrheal.		Under 5 Years.	
		Per 100 000.	Per cent. all deaths.	Per 100 000.	Per cent. all deaths.	Per 100 000.	Per cent. all deaths.
1879–83	20.2	27	1.48	204	10.9	789	43
1884–88	20.0	42	2.11	263	13.1	891	45
1889–93	18.2	44	2.43	256	14.1	690	38
1894	17.8	12	.69	216	12.1	580	32
1895–99	18.5	16	.86	182	9.8	668	36
1900–04	17.6	25	1.40	161	9.2	609	35
1879–1904	18.4	29	1.58	208	11.2	708	38
1905	21.0	15	.68	232	11.1	700	34

TABLE No. 4. — Monthly Distribution of Typhoid* Mortality at Burlington, Vt., 1879 to 1905, Inclusive.

	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Total.*
1879..	..	..	..	..	1	..	..	..	..	..	..	1	2
1880..	..	1	..	..	1	..	1	..	..	..	..	..	3
1881 ..	..	..	..	..	..	..	..	..	1	..	1	..	2
1882..	..	3	2	..	..	..	..	..	..	1	2	..	8
1883..	1	..	..	..	..	..	..	..	..	..	..	..	1
1884..	1	..	..	..	..	2	4	2	..	1	..	..	10
1885..	..	..	..	..	..	1	..	..	..	..	..	..	1 (1)
1886..	..	..	..	..	..	2	..	..	1	1	..	..	4 (2)
1887..	2	..	..	1	..	..	..	..	..	..	..	1	4 (2)
1888..	1	..	..	1	..	1	1	..	3	1	..	1	9 (5)
1889..	1	2	..	1	..	..	..	1	1	1	..	1	8 (2)
1890..	..	1	1	..	..	..	1	..	..	..	..	1	4 (3)
1891..	..	3	..	..	..	..	..	..	..	..	1	..	4
1892..	1	..	1	..	..	..	..	1	..	2	1	1	7 (4)
1893..	1	4	2	..	1	..	..	1	1	..	..	..	10 (2)
1894..	..	1	..	..	..	..	..	1	..	..	..	..	2 (1)
1895..	..	..	..	..	..	..	1	..	..	..	..	..	1
1896..	..	1	..	..	..	1	1	1	..	..	..	..	4 (3)
1897..	..	..	..	..	..	1	1	..	..	..	..	..	2 (1)
1898..	1	1	1	..	..	..	..	..	1	1	..	..	5 (1)
1899..	..	..	1	..	..	..	..	1	..	..	..	..	2 (1)
1900..	2	2	..	..	..	..	..	..	1	1	..	1	7
1901..	1	..	2	1	..	..	..	..	..	..	1	..	5 (1)
1902..	..	..	..	1	..	..	..	..	..	..	..	1	2
1903..	..	..	..	..	1	1	..	1	..	..	..	..	3
1904..	..	..	1	..	..	1	2	..	1	1	1	..	7
1905..	1	..	1	..	..	..	..	..	..	..	..	1	3
Total	13	19	12	5	4	10	12	9	10	10	7	9	120 (29)

* Included in the typhoid mortality as here given are, for the whole period, 29 cases classed in the city reports as bilious and other fevers. The totals by years are given in parentheses at the right in the last column; in detail they are as follows:

1885. — 1 typho-malarial fever in June.
1886. — 1 bilious fever in June; 1 slow fever in September.
1887. — 1 typho-malarial in May and 1 in December.
1888. — 1 continued fever in April, 1 in July, 2 in September, 1 in October.
1889. — 1 continued in February; 1 enteric fever in April.
1890. — 1 continued in July; 1 typho-malarial in March and 1 in December.
1892. — 1 continued in January and 1 in December; 1 enteric in October; 1 typho-malarial in August.
1893. — 1 bilious in February; 1 continued in March.
1894. — 1 bilious in August.
1896. — 1 continued in August; 1 typho-malarial in February and 1 in June.
1897. — 1 bilious in June.
1898. — 1 bilious in October.
1899. — 1 bilious in August.
1901. — 1 bilious in January.

1885 to 1901: Continuous, 11; typho-malarial, 8; bilious, 7; enteric, 2; slow, 1.

The deaths classed as typhoid in the above table have been rearranged by months from highest to lowest, as follows: February, 19; January, 13; July, 12; March, 12; June, 10; September, 10; October, 10; August, 9; December, 9; November, 7; April, 5; May, 4; total, 120. The monthly mass average is 10.

By quarterly periods the grouping, from highest to lowest, is: January–March, 44; July–September, 31; October–December, 26; April–June, 19; total, 120.

TABLE No. 5. — BURLINGTON WATER ANALYSES AVERAGED BY YEARS.

(Chemical results in parts per 1 000 000; bacterial in 1 c. c.)

	Number of Samples.	Bacteria.		Chlorine.	Ammonia.	
		Total.	Coli Present.		Free.	Albuminoid.
1899	27	268	Not reported	1.4	.031	.141
1900	38	529	Not reported	2.3	.039	.139
1901	24	1 293	7 of 24	.9	.021	.134
1902	66	617	13 of 65	1.1	.014	.115
1903	49	641	8 of 49	1.1	.011	.113
1904	50	782	13 of 49	1.0	.012	.114
1905	49	172	12 of 49	1.1	.014	.121

* The nitrates and nitrites were first reported in 1903. The nitrates have been as follows, in parts per million: 1903, .190; 1904, .180; 1905, .187. No nitrites were found during these three years.

The total solids for 39 samples collected during 1905 ranged from 95 parts per million on October 11 (the last sample for the year), with a loss on ignition of 37, to 58.5 parts on May 5, with a loss on ignition of 14. The maximum figure given was abnormal, 75 having been exceeded only five times.

The chlorine for the least polluted portions of Lake Champlain does not seem to have been determined. Water Supply and Irrigation Paper No. 144 (United States Geological Survey) shows the lake lying between Isochlors 0.3 and 0.4 (parts per million), but the normal chlorines of waters in towns near the lake, in the vicinity of Burlington, average about 0.5. The range of chlorine found in the samples included in the above table has been from 0.4 to 3.4. By years this range has been: 1899, 0.6 to 2.0; 1900, 1.6 to 3.4; 1901, 0.4 to 1.4; 1902, 0.8 to 1.5; 1903, 0.9 to 1.4; 1904, 0.8 to 1.3; 1905, 0.9 to 1.3. The 3.4 figure, like a number of others for 1900, was for a sample drawn from one of the reservoirs.

See Professor Sedgwick's paper (JOURNAL OF NEW ENGLAND WATER WORKS ASSOCIATION, Vol. X, p. 174) for 28 analyses, mostly of samples from various points in the lake, made from 1882 to 1889, inclusive.

TABLE No. 6. — B. Coli Communis in Daily Samples of Water from the Burlington Water Supply, February, 1904, to January, 1905, Inclusive.

(Examinations of 1 cc. of water made at the Vermont State Laboratory of Hygiene. B. H. Stone, M.D., Director and Bacteriologist; P. S. Carpenter, Assistant Bacteriologist.)

Month 1904-5.	Number of Daily Samples.	Per Cent. of Samples Positive.	Month.	Percentages Rearranged, Greatest to Least.
February	29	34	December	60
March	31	45	January	57
April	30	36	October	53
May	29	51	May	51
June	28	51	June	51
July	28	25	March	45
August	31	31	April	36
September	16*	31	February	34
October	31	53	November	33
November	30	33	August	31
December	28	60	September	31
January	26	57	July	25
Year	337	44†	Year	44†

* Vacation taken this month.

† Percentage for year based on totals for the year and not merely an average of the monthly percentages; that is, of the 337 samples examined, 147, or 44 per cent., gave positive results.

TABLE No. 7. — Lengths in Miles of Streets, Sewers, Water Mains, and also Populations and Water Consumption, Burlington, Vt., at Stated Intervals.

	Length in Miles of			Population.	Average Daily Water Consumption, Gals.	
	Streets.	Sewers.	Water Mains.		Total.	Per Capita.
1880	(50*)	6.14	(20*)	11 365	600 000	53
1885	...	8.54	28.7‡	12 980	621 812	48
1890	53.0	14.07	30.4‡	14 590	756 401	52
1895	54.9	18.76	35.7‡	16 615	888 083	53
1900	55.5	23.91	38.0‡	18 640	857 250	46
1904	56.6	27.50	40.0‡	20 260	987 158	49
1905	56.9†	28.20	40.0‡	20 665	1 056 008	51

* In 1882 ; not reported in 1880.

† Paved and macadamized, 22.8 miles; graveled, 17.1 miles.

‡ Not including pipe under 4 inches in diameter, which was 5.8 miles in 1885 and 4.8 in 1905.

The present water works were put in operation on December 25, 1867. Mention of the " present sewer " was made in the annual report for the year ending February 1, 1868.

An unusually high percentage of the total population has been supplied with water for many years, according to the annual reports of the water department. As early as 1885 it was estimated by the water department that all but 700 of the population was supplied with city water; in 1905 the unsupplied population was likewise given as only 400. The number of taps or services at the close of 1905 was 3 634, or over 1 per 6 of estimated population; at the same time there were 2 867 meters in use, or 79 per cent. of the total number of taps.

DISCUSSION.

MR. ROBERT S. WESTON.* *Mr. President and Gentlemen of the Association,*— The speaker had the good fortune to look over Mr. Baker's paper in advance. It certainly is a piece of very serious and very careful work. Last night some here enjoyed the privilege of listening to Mr. Baker's after-dinner speech at the annual dinner of the Boston Society of Civil Engineers, in which he took occasion to plead for a broader training for engineers and a more thorough study of engineering problems, especially of sanitary engineering problems, saying that these questions should be studied statistically and not *a priori*.

Such suggestions are very timely, especially when one considers that progress in sanitary science must be based upon vital statistics and that vital statistics are often grossly inaccurate. One has heard of the scholar in politics and the scholar in art; in this paper Mr. Baker expresses the life of the scholar in sanitary science.

In looking over this paper it is especially interesting to note how many more infants there are who die from diarrheal diseases than there are people who suffer death from typhoid fever. The ratio is something like 20 to 1. If these other diarrheal diseases were statistically treated, so that they could be given engineering notice, they would certainly be a worthy subject for frequent discussion in connection with the purity of our water supplies. Health officers frequently say: "Why do engineers always harp upon the typhoid fever death-rate?" And engineers reply: "That is the only group of vital statistics which we can treat as a reality, as a basis for any definite engineering work and expenditure of money." It is certainly very gratifying to read Mr. Baker's scholarly research into the vital statistics and his attempt to solidify the basis for the design and construction, operation, and protection of water supplies.

In this connection it is quite interesting to remember Mr. Hazen's remarks at the International Engineering Congress at St. Louis, when he said that the experience in Albany and in several other cities which he had studied, was that for every reduction of 1 per 100 000 in the typhoid fever death-rate, there

* Sanitary Expert, Boston, Mass.

seemed to be a corresponding reduction of 3 or 4 in the general death-rate. That, if true, certainly would be in confirmation of Mr. Baker's paper.

Two things are quite noticeable at Burlington. *First*, there is a rather uniform distribution of typhoid fever throughout the year, while in many other cities typhoid fever seems to reach its height in the fall. This would point to the absence of what one calls vacation typhoid, and to the existence of typhoid due to local causes. *Second*, the water, even though polluted, is of agreeable appearance, so that the whole community partakes of it and does not, as they do in many other cities, resort to spring and well waters of doubtful history. The problem at Burlington is uncomplicated by such side issues as these.

There are two fallacies in regard to the public health, which, in the speaker's opinion, would be exposed by the public health statistics; namely, what for lack of better terms may be termed the hospital fallacy and the prosperity fallacy. One frequently hears people say, as is written in Mr. Baker's paper with a question mark: "Our city has a higher typhoid fever death-rate in comparison with other cities because we have a hospital in our city; because this hospital draws upon the surrounding country for patients, and because the deaths of these out-of-town patients are included in the statistics." In opposition to this idea one should remember that many people go away from home and die of typhoid fever. One should also remember that every large center of population has a hospital, and naturally every large center of population draws upon the surrounding country for the support of that hospital. Even in suburban towns and cities there are hospitals,— Waltham, Newton, Brockton, Fall River, Taunton, Lowell, Lawrence, all have hospitals, — and in comparing statistics we are comparing the statistics of cities in all of which there are hospitals. Therefore it does not seem to the speaker that the health officer is justified, when he speaks about the typhoid fever death-rate in a city, in excusing lack of sanitary excellence because of the presence of a hospital, unless all the figures are given.

Then there is another fallacy, which may be called the prosperity fallacy, which is this : People say, "Our community is a

very prosperous community, a rich community, and every summer a large number of people go away on vacations, and when they come home they bring typhoid with them. This typhoid fever is not due to conditions in our city, but it is due to the conditions of the summer vacation." There is a great deal of truth in this statement, of course, but the speaker does not think it explains everything by any means (for example, why the wealthy cities frequently have low typhoid), and urges that in studying public health questions the statistical method be used,—but not the statistical method which Dr. Carroll D. Wright exemplifies when he says, " Statistics do not lie, but statisticians sometimes do."

It is a great pleasure to praise Mr. Baker's work and his paper, both for their scientific spirit and their spirit of public service.

PROF. C.-E. A. WINSLOW.* I have listened with very great pleasure to Mr. Baker's paper, not only for the results which have been obtained, but also as a study in method to be pursued. This is one of those cases where the damage was of the kind that could not be detected and proved by any gross methods. It needed the careful use of statistics and the careful analyses of bacteriological and chemical data to prove it; but it has been proven here, I think, without a shadow of a doubt. Of course statistics are difficult things to handle. In the first place, in this country there are only a comparatively few cities and towns that have good vital statistics; and in the second place, statistics require expert skill and care in handling after they are collected. When, as in this case, you have statistics which have been well collected, and which are ably analyzed, you are on safe ground. One table which Mr. Baker has been good enough to let me look over shows the typhoid deaths by months for a period of years, and I think an inspection of that table alone would be enough to convince any one familiar with typhoid fever that most of the typhoid in Burlington is due to the water supply. In the first place, if milk epidemics were important, the typhoid deaths would be grouped together, a considerable number in a single month, because a milk epidemic almost always effects a considerable number of people at the same time. That is not the case here. The deaths occur two or three at a time only, and there are no

* Massachusetts Institute of Technology, Boston, Mass.

large epidemics. In the second place, the point to which Mr. Weston alluded is not significant, the typhoid deaths being rather evenly distributed over the year, showing even, as Mr. Weston did not state, a slight concentration in the winter and in the early spring.

Now, as Professor Sedgwick has pointed out at a previous meeting of this association, there is a clear distinction between the distribution of typhoid fever by seasons, when it is due to water and when it is not. When typhoid fever is due to causes other than water it has a regular seasonal curve. The typhoid germ is quite susceptible to the temperature, and in cities not having a polluted water supply the disease increases in the autumn, reaching its height in September and October. That is almost an invariable rule, as has been shown by the study of statistics all over the globe. On the other hand, where you have a polluted water supply, typhoid deaths are most apt to occur in the winter, not in midwinter, but at the beginning of the winter when there are heavy rains, and at the end of winter when the thaws come, because those are the times of flood when most polluting material is washed into the water supply. The figures for Burlington show exactly that distribution, and there can be no doubt that the typhoid deaths are due mainly to the water supply.

Again, I think this paper furnishes very valuable testimony as to the importance of bacteriological analyses. The commonly accepted standard is that water which is good to drink should not give a positive test for the colon bacillus in one cubic centimeter certainly not over 50 per cent. of the time. We have lacked data to enable us to fix the standard very closely, but that has been considered a conservative estimate. This paper suggests that perhaps that estimate is a little too high. The analyses in Burlington, where there was a slight pollution, and only a slight pollution, when compared with the water supplies of Philadelphia and Pittsburg, and many other cities, show the colon bacillus in about 40 per cent. of the samples, I think. This shows that we certainly have not been too stringent in insisting upon the 50 per cent. limit, and it suggests that we should probably insist on still greater purity.

There is just one other point I should like to say a word about,

and that is the very important question of the deaths of young children, to which Mr. Baker has alluded. Very few people who have not studied vital statistics realize the importance of this factor in the death-rate, or comprehend that in some communities from 30 to 40 per cent. of the total deaths occur under five years of age. That is the case in many of our large cities, and it is the case in Burlington. It means that perhaps a fifth or two fifths of the children born are swept out of existence before they are five years of age. I do not think that any large part of this death-rate can be attributed to water. In the first place, the deaths are largely of children under one year; and it has been shown by extensive studies in Germany and elsewhere that for the most part this death-rate is due to milk, and to cow's milk, and to rotten cow's milk, — that is, it is due to a poisoning from the putrefaction of cow's milk before the children are fed upon it. But whatever it is due to, it certainly behooves every one to see that the matter is properly studied.

I believe that a great deal can be gained by inciting, as Mr. Baker has apparently wished to do, boards of water-works officials to watch health boards. Health boards already exercise a pretty close supervision over water-works officials, but I think the rule should work the other way, too. It seems to me that every public-spirited citizen, and certainly every water-works official, should study the vital statistics in his own town and find out if there is an excessive death-rate among children. If water is not the cause, he should get after the health board, the proper officials, the people who should supervise the milk supply, and other sanitary dangers, and have them see to it that conditions are remedied.

B. H. Stone, M.D.* It is with much hesitation that I venture to discuss a paper which I have not had the opportunity of hearing, and probably some things which I say would remain unsaid if that opportunity had been mine. I am, however, fairly familiar with Mr. Baker's views of the Burlington water question as expressed in his report prepared for the Special Water Committee appointed to consider the question of a new supply. With most of the views expressed in that report I am in accord. There are a few features of the situation which Mr. Baker passes over as of little importance,

* Laboratory of Hygiene, Burlington, Vt.

to which we at the Laboratory of Hygiene are inclined to give more weight. Mr. Baker suggests that the discussion be along the following lines:

1. Leakage of intake pipes and analytical means of detecting it.

2. Dangers from the sewage of Burlington as compared with that of Winooski and Fort Ethan Allen.

3. Typhoid records at Winooski and Fort Ethan Allen.

4. Typhoid at the Mary Fletcher Hospital.

5. Influence of out-of-town inmates at the hospital and two children's homes upon the general death-rate and other mortality figures as given in Table No. 1.

In regard to the first point, little can be said from the sanitary aspect beyond what has already been said. We have, so far as I know, no analytical data to prove such an accident. Specimens of water taken over our own intake resemble very closely those taken from our service pipes. On the other hand, it is perfectly evident from the slight analytical difference between water taken in the region of the intake and much nearer shore, as is brought out in Mr. Leighton's paper on the " Pollution of Lake Champlain," that a large admixture of shore water would be possible without any appreciable analytical change to prove its presence. This problem seems to me to be one which must be attacked from an engineering rather than from a sanitary standpoint.

With regard to the second point suggested by Mr. Baker for discussion, *i. e.*, the dangers from the sewage of Burlington as compared with that of Winooski and Fort Ethan Allen, I must take some exception. Mr. Baker passes over the Winooski River as of little importance in the Burlington water problem, while we are convinced that it is a factor of real importance, and perhaps the most dangerous source of infection to our water supply. Our grounds for this opinion are based upon the following propositions which we think are capable of proof :

1. That Winooski and Fort Ethan Allen pour into the river the raw sewage of a population of approximately 5 500.

2. That the topography of the region is such as to render it possible, and even probable, that some portion of this sewage may reach this intake.

3. That we have optical evidence that our water is affected by the river at times of flood.

4. That there is an increase of diarrheal diseases following high water in the Winooski River.

The population of Winooski has increased very materially since the new intake was put in operation in 1894, and Fort Ethan Allen, with its population of 1 500, has been established since that date. This post was first occupied in 1894, when three troops of cavalry arrived there. Since that time it has gradually increased in size, until now it is the second largest military post in the United States, having a continuous population of about 1 500 men. The Winooski River receives the sewage from this post a short distance above Winooski. That the water is highly polluted when it reaches Winooski is amply proven by a large amount of analytical data, some of which is published in Mr. Leighton's paper and some of which appears in the various reports of the Vermont State Board of Health. A striking evidence of the danger of this pollution was brought out by a recent experience in the village. One year ago this winter the Winooski water supply proved insufficient and arrangements were made to use the Burlington water. There was some delay in making the connections and the authorities were forced to allow the untreated river water to flow through the pipes for about twenty-four hours; although people were warned against drinking it, some twelve or fifteen cases of typhoid occurred within the next two weeks.

Float work which has been done by Professor Votey, although not yet completed, shows that the time required for water to pass from Fort Ethan Allen to the mouth of the river is in the vicinity of seventeen hours. The distance from the village of Winooski to the mouth of the river is not over two miles, but on account of its tortuous course, the river flows nearly ten miles in making that distance. In spite of this, the water at the mouth of the river is badly polluted, as has been proven by analytical data taken at various seasons of the year through the ice and in the summer months. This pollution can be traced analytically for a considerable distance from the mouth of the river. The current of the river at its mouth is south. The shore currents of the lake inside the promontories, as proven by Mr. Leighton, are southern,

From the mouth of the river to the intake the distance is about three miles. For 2¾ miles of this distance the water is nowhere over ten feet in depth, and for the last quarter of a mile not over twenty-five feet. Now at times of low water it is probably very true, as suggested by Mr. Baker, that the sewage from Fort Ethan Allen and Winooski is largely taken care of by sedimentation and other natural causes, but in times of high water these causes are not in operation, and the highly polluted waters rush over the sand flats at the mouth of the river, strike the southern lake currents, and are carried directly over the region of our intake. That this is true is plainly demonstrable after such a period of high water. At such a time the line of muddy water can be noted passing almost as far south as Juniper Island and circling around Apple Tree Point over the intake. A photograph which I enclose * shows this rather poorly. At such times drift wood coming from above Fort Ethan Allen as far up as Essex Junction is found, from twelve to twenty-four hours after, strewn along the shores of Sunset Bay, having passed the entire distance down the river and over the intake in this time. After such a period of high water, the water coming into our reservoir and passing through our service pipes shows a decided increase in turbidity for several days. That this muddy water carries with it sewage organisms is plainly evident from the fact that we are always able to detect the colon bacillus from our service pipes at such a time, and that such high water is invariably followed by an unusual number of cases of typhoid and diarrhea. Such an occurrence happened this winter following one of our rapid thaws. The water was so muddy that a very perceptible sediment would collect in the bottom of a glass. In the next two weeks there were eight or ten cases of typhoid, and diarrhea was almost universal. At times of high water, of course, the dilution of sewage is great; but sedimentation does not take place, and the rapidity of the flow is so much greater that the reduction by dilution is more than compensated. Furthermore, in such a time of thaw, much filth which has accumulated on the frozen ground is washed into the river. Although the fact of this great dilution will probably prevent any considerable epidemic of typhoid at such times, we believe that in its present position

* Not reproduced. — Ed.

our intake is more in danger by this source of pollution than by Burlington sewage. It is rather a strange coincidence that Fort Ethan Allen was established on the Winooski River, increasing this so materially as a source of contamination, in the same year that our intake was removed so much nearer to the mouth of this river.

Burlington sewage, barring the effect of the winds, is influenced by the general southern shore currents of the lake which sweep it south into and by Shelburne Bay, where it circles north again between Burlington and Juniper Island, when it is separated from the intake by two miles of deep and comparatively still water. Sedimentation is much more operative here than in the moving waters of the river. In the specimens taken by Mr. Leighton and examined in this laboratory, some specimens taken in the deep water on the line between the mouth of Shelburne Harbor and the intake showed no colon bacilli, and showed a water quite nearly like the normal water of the broad lake.

I am enclosing the typhoid and diarrhea statistics from the hospital at Fort Ethan Allen. (Table No. 8.) I was unable to procure satisfactory statistics from Winooski. I am also enclosing a table which shows the number of cases from Burlington which have been examined for typhoid by the Widal reaction at this laboratory. (Table No 9.) I have given figures for the positive and negative cases, as those which failed to give the reaction would naturally come under the diarrheal diseases. It will be noted that the number of positive cases in every instance is larger than the number reported to the health officer. This indicates in my mind that a good many cases of genuine typhoid are probably not reported.

I am inclined to think that the out-of-town typhoid cases which are treated at the hospitals and the two homes are of very little importance, as all of these institutions avoid taking these cases, and when so taken they appear on the reports.

TABLE No. 8.—Statistics of Typhoid Fever and Diarrhea at Fort Ethan Allen.

Year.	1906	1905	1904	1903	1902	1901	1900	1899	1898*	1897	1896	1895	1894
Typhoid	—	3	1	1	—	1	—	1	6	—	1	1	4
Dysentery	—	1	—	4	3	5	—	1	6	—	1	—	—
Diarrhea	7	23	41	24	40	31	—	24	47	17	15	6	5

* In the fall months of this year (1898) the First Vermont Volunteers were stationed here, coming from Camp Thomas. During the time of their stay there were fifty-five (55) cases of typhoid treated at the Post Hospital. These cases do not appear in the above table.

The case of dysentery noted (1905) was acquired in Philippine Islands.

This excerpt from Post Hospital records dates from October 1, 1894, to present month of March.

All records for the volunteer forces stationed here at any time have been sent to surgeon-general's office, Washington, D. C.

C. R. Robbins,
Captain and Assistant Surgeon, U. S. A.

TABLE No. 9.—Burlington Fever Cases which have been Subjected to the Widal Test at the Laboratory of Hygiene, Burlington, Vt.

Year.	Positive.	Negative.	Year.	Positive.	Negative.
1898	41	31	1902	20	24
1899	43	22	1903	29	68
1900	52	34	1904	56	32
1901	37	54	1905	77	113

Mr. C. P. Moat.* Since any statement of my opinion on the question of the influence of the Winooski River on the intake of the Burlington water works would be simply a repetition of Dr. Stone's remarks, as our ideas on this question have always been in full accord, I will simply submit some additional data on the quality of the water of the Winooski River. In addition, I send as much information on the number of cases of typhoid fever in the village of Winooski as is at present available (Table No. 10).

* Chemist, Vermont State Board of Health, Burlington, Vt.

These data are taken from the number of specimens sent to the Laboratory of Hygiene for the Widal test and are probably more accurate than the number of cases reported to the health officer, which is not available at this time.

In the table of water analyses (Table No. 11), the samples were taken from the Winooski River in the following places:

I. Several hundred feet above the outlet of the sewer of Fort Ethan Allen.

II. Below the outlet of the sewer of the fort (sample was taken near shore and current of river was towards that shore).

III. Above the upper dam at the village of Winooski.

IV. Below the village of Winooski. (Sample was discolored and contained very high chlorine, probably caused in part by mill waste, but as yet we have had no opportunity for further study of this problem. We hope to do more along this line this spring.)

V. Sample taken at the temporary intake of the Winooski Aqueduct Company at the American Woolen Company's mill at village of Winooski. This sample was taken at the time mentioned by Dr. Stone, when the river water was allowed in the mains of the Winooski Aqueduct Company for twenty-four hours, causing much typhoid, as shown in year 1903-4 of Winooski typhoid table.

VI. Sample taken at railroad bridge near the mouth of Winooski River.

Besides these analyses, further data may be found in the Water Supply Paper, United States Geological Survey No. 121, Tables xxii and xxiii and Fig. 7.

TABLE No. 10.—SPECIMENS EXAMINED AT LABORATORY OF HYGIENE FOR TYPHOID FROM WINOOSKI.

Year.	Results.		
	Positive.	Negative.	Total.
Nov. 1, 1898 – Dec. 1, 1900,	5	11	16
1900–1901	6	16	22
1901–1902	2	7	9
1902–1903	4	9	13
1903–1904	18	38	56*
1904–1905	7	18	25

* Year in which river water was used for twenty-four hours.

TABLE No. 11. — Analyses of Water from Winooski River. (Parts in 1 000 000.)

	Date of Collection.	Appearance.			Odor.		Residue on Evaporation.			Ammonia.		Chlorine.	Nitrogen as		Oxygen Consumed.	Hardness.	Bact. per 1cc	B. Coli.
		Turbidity.	Sediment.	Color.	Cold.	Hot.	Total.	Loss on Ignition	Fixed	Free.	Albuminoid. Total.		Nitrates.	Nitrites.				
I	Nov., 1905	sl.	sl.	14	1e.	—	71.	20.	—	.008	.106	.7	.230	.000	—	41.6	300	present
II	Dec., 1905	dec.	,,	12	5d.	—	60.	10.	—	.150	.250	1.4	.250	.000	—	——	420	,,
III	Nov., 1905	sl.	,,	24	2e.	—	70.	10.	—	.010	.098	1.1	.200	.000	—	41.6	500	,,
IV	,, ,,	,,	,,	30*	,,	—	82.	22.	—	.044	.116	3.5	.140	.000	—	48.6	400	,,
V	Jan., 1904	dist.	,,	30	3e.	—	87.5	11.5	—	.076	.100	1.6	.600	.003	—	62.9	1 000	,,
VI	Mar., 1901	dec.	cons.	30	2v.	—	54.8	14.	—	.068	.194	1.6	.340	.001	—	36.	many	,,

* Discolored.

MR. M. O. LEIGHTON.* The subject of this paper is of great interest to the writer. During the summer of 1904 he had occasion to look into it to some extent in connection with an investigation maintained by the United States Geological Survey upon the pollution of Lake Champlain. Among the results of that investigation was a demonstration of the fact that, although the water in the broad lake did not contain bacillus coli communis, the entire area in front of the city of Burlington, and from thence northward to and beyond Apple Tree Reef, the point of the present intake, was infected by Burlington sewage. This was shown by the almost constant appearance of coli in the samples collected.

Mr. Baker's first table shows that, although no relation is apparent between the total deaths and the number of deaths from typhoid, the number due to diarrheal diseases appears to fluctuate with the total in an extremely interesting manner. The large number of fatalities from diarrheal diseases is a distinct factor in increasing the general death-rate at Burlington.

Another interesting fact shown by Table No. 1 is the apparent faithfulness with which the cases of typhoid fever have been reported in Burlington since 1898. The writer is now referring to those cases which are well marked and easily diagnosed and recognized by the practitioner. It appears from a review of the report of the Medical Commission appointed to investigate the origin and spread of typhoid fever in the United States military camps during the Spanish War, that 7.61 per cent. of the typhoid cases were fatal, while American hospital experience in general seems to show that about 9.25 per cent. are fatal. Assuming that 8 per cent. is a conservative figure, it will be seen that there is an unusual faithfulness on the part of the physicians in reporting typhoid cases, the reports in some years being equal to the probable actual cases as comported upon this basis.

Of course we know that a great many of the deaths reported as being due to diarrheal diseases were actually the result of typhoid, and if the numbers were known, they would probably constitute a surprising proportion of the whole. It will be remem-

* Chief of Division of Hydro-Economics, United States Geological Survey, Washington, D. C.

bered that the investigation of the Medical Commission above referred to showed that the army surgeons diagnosed about one half the cases of typhoid fever in military hospitals during the Spanish War, and it has not been shown that physicians in civil life betray a much greater degree of success in general diagnostic ability than those in the army.

Another interesting point emphasized by Table No. 1 is that every important change that has been made in the sewerage and water-supply systems of Burlington has been followed by a marked reduction in either the number of deaths from typhoid or from diarrheal diseases, and it illustrates how misleading may be the statistics of a single year or of a short period. It will be noted in Table No. 1 that there were 79 deaths per 100 000 from typhoid in 1884, but in 1885, the date when the main outlet sewer was moved one-half mile farther away from the water intake, there were only 8 deaths per 100 000. Similarly, in 1894, the year after the removal of the water intake from the northern dock limit in the city out to Apple Tree Reef, there was a reduction in the number of typhoid deaths of from 63 to 12 per 100 000, and this reduction, by the way, persisted for several years. It is further particularly interesting to note that, in 1898, the date of the placing in commission of the new storage reservoir, there followed an enormous reduction in the deaths from diarrheal diseases. It appears that none of these changes have effected a permanent benefit in Burlington, and yet, if the statistics immediately following the dates of those changes be taken alone, wondrously deceptive statements may be made.

Mr. Baker's Table No. 2 shows that among the fatal diarrheal diseases, cholera infantum comprises a very large proportion. Presumably, this infantile trouble is due in only a minute degree to the public water supply, and the deaths probably all occurred during the hot months. It would be interesting to have a statement of the seasonal distribution of the deaths from these diseases, because it is especially important to know whether the greater proportion of them, other than cholera infantum, occurred during the winter months, when the lake is coated with ice. If such is the case, the evidence against the water supply would be even more conclusive than it appears from the results presented. It would

be interesting, too, to compare the diarrheal morbidity in Burlington during the winter season with that in Michigan City, Ind., where each winter, up to the time that the Chicago sewage was diverted from Lake Michigan, they had an epidemic of what was locally known as "winter cholera," due undoubtedly to the infection of the lake supply by Chicago sewage. The infection was rapidly transmitted along the south shore of the lake by prevailing northerly winds and confined and concentrated under the ice sheet which usually forms there.

In connection with Table No. 2-A, which shows that during about one third of the time since the year 1880 Burlington has had an abnormal typhoid rate, it is interesting to notice that all the abnormal years, except two, occur previous to the extension of the water intake to Apple Tree Reef. From 1880 to 1894, abnormal typhoid rates appear about every second or third year, but during the eleven years subsequent to this extension, the rate has been abnormal during two years only. The same condition is exemplified in the deaths from diarrheal diseases. Accepting the rate of 20 per 100 000 as an arbitrary division between normal and abnormal diarrheal disease death-rates, it will be seen from an examination of Table No. 1 that during the years up to 1894, the abnormal death-rate largely predominated, while since that time the abnormal rate has appeared only on three occasions.

Table No. 3 emphasizes the improvement brought about by the extension of the conduit in the year 1894, and shows clearly the gradual return to the old conditions during more recent years. Why, in the lapse of years since the extension of the intake, there should have been a gradual return to former conditions, is a question which can hardly be answered with the present information. There are some reasons for believing that the continued discharge of Burlington sewage into the lake has increased the infected area until it now reaches to the intake at Apple Tree Reef. The series of samples taken in front of Burlington in September, 1904, along the line shown in Fig. 7, page 87, of Water Supply and Irrigation Paper No. 121, United States Geological Survey, would seem to indicate a very general extension of the infected area, coli communis being present in nearly all samples. That this is not a natural condition is shown, as stated at the beginning of this dis-

cussion, by the fact that in the broad lake, coli communis does not appear to be present.

There is also some reason for believing that the conduit extending from the pumping station to Apple Tree Reef may have developed leaks, which are responsible for a return of the old conditions of typhoid and diarrheal morbidity. This matter could and should be thoroughly investigated. The conditions of the investigation are such that the work would have to be directed along bacteriological lines and, in fact, just here is presented one of the unmistakable cases in which the value of bacteriology in connection with water investigation is shown. In order that the work may be of value and the results be made dependable, special preparations should be made, and a competent man should give his entire attention to every detail of the investigation.

Daily and, if possible, semi-daily samples should be taken from the mouth of the intake at Apple Tree Reef and from some point along the conduit after it emerges from the lake, possibly at the pumping station. These samples should be taken in series. Bacterial counts and tests for coli communis should be made, and a comparison of the two series should show conclusively whether or not the conduit admits infected water through leaks developed since the laying thereof. Besides being of immense local value, such an investigation would be of interest from a general scientific standpoint and would be useful reference for all future water investigations of a like character.

One of the most important evidences concerning the culpability of the water with reference to the production of typhoid in Burlington is contained in Table No. 6. It is especially significant that the highest typhoid rates occur during the season when the lake is covered with ice, when there is, one might say, a short circuit between the sewer outlet and the water intake. If we examine the seasonal distribution of urban typhoid throughout the United States, it will be found that quarterly periods from highest to lowest are (1) September to November; (2) December to February; (3) June to August; and (4) March to May; while, according to Mr. Baker's groupings, the highest quarterly period at Burlington is January to March, during which season Lake Champlain is generally coated with ice.

Mr. Baker's Table No. 5 affords a concrete illustration of the value of coli tests in revealing dangerous pollution in a water, while, on the other hand, the general futility of the nitrogen determinations for such purposes is amply demonstrated. In fact, throughout all the Burlington investigations, the nitrogen determinations have been of no aid in tracing the cause of disease and, as a whole, the case forms one of the best of a great many which demonstrate the general uselessness of the time-honored determinations of free and albuminoid ammonia, nitrites and nitrates, in surface water investigations.

Mr. Baker's observation that the pollution of Winooski River has probably very little to do with the infection of the water supply is supported to a large extent by observations of the writer. There are times, however, during seasons of prevailing northerly winds and of floods in the Winooski, when the path of the stream may be clearly marked along a course extending well to the south and not far from the present water intake. The general trend of the current, however, is northward from Winooski River, and it is therefore probable that such infection does not, in the majority of cases, extend as far south as Apple Tree Reef.

MR. ALLEN HAZEN.* Mr. Baker's paper is an extremely interesting contribution to our knowledge of the relations between water supply and public health. The most unfortunate feature connected with the case is the uncertainty as to whether the intake is tight, and whether all the water comes from the intended place, or whether there are leaks in the pipe line which admit more highly polluted water from the bay; and it seems particularly unfortunate that this matter was not settled beyond question before Mr. Baker completed his studies and made his report.

Mr. Baker has referred to the investigations of the use of polluted water by cities, made twelve or fifteen years ago, in making which I had the privilege of being associated with our honored President, Professor Sedgwick. The change that has taken place since that time in the aspects of this question is a most significant commentary on the development in the interval; and I wish to make a few comparisons which may help us to realize the extent of the progress which has been made.

* Civil Engineer, New York, N. Y.

At the time mentioned, the relations between public water supply and disease were by no means generally recognized. And this is the more surprising, as many of the larger American cities were using grossly polluted waters, and as a result suffered from death-rates greatly in excess of what they would otherwise have had.

The question as to the accuracy of the vital statistics at our disposal then was far greater than it is now, but the effect of the polluted waters upon the health of the communities using them was so great that no refinements were necessary to bring out the general relations which existed. The contrasts between the large cities using different kinds of water were so great that it was hardly conceivable that errors in classification or in failures to report deaths, however flagrant they might have been, would have sufficed to modify the conclusion that the enormous excess of sickness and death in some American cities was directly due to the use of grossly polluted water supplies.

These conclusions, nevertheless, were at first bitterly contested in many quarters; but as they were studied further the logic of the situation became apparent, and they came to be generally accepted. Since then affairs have changed; and while there are still some black sheep in the fold, on the whole there has been a great improvement in the average quality of the public water supplies of the country, and the recognition of the relation between the character of the water supply and the health of the community has been a tremendously important element in bringing about this improvement.

At that time such an investigation and analysis as Mr. Baker has now made of the pollution of the Burlington water supply would have been out of place. Then it would have been difficult, perhaps impossible, to have established the relations between the moderate pollution of the water and the moderate increase in the death-rate from certain causes resulting from it, which Mr. Baker has found to exist in Burlington. Now it is possible. It is possible because, in the first place, the proposition that such a relation does exist is a corollary of the main proposition that highly polluted waters do produce excessive death-rates; and it is further possible because, in spite of existing defects, the information available to aid in the study of such a problem to-day is

vastly better than could have been obtained a dozen years ago. The vital statistics are better, and the laboratory examinations of the water are vastly better than could possibly have been obtained at that time.

This investigation of Mr. Baker's, I think, is but a typical case of many such investigations that are going to be made to determine the effect of less grossly polluted waters upon the public health. The methods of investigation are improving as time goes on, and by proper use of them it is possible to follow the relation between water supply and disease further down the line and carry it to degrees of pollution the effects of which were at first too small to be observed or studied; and such investigations will extend our knowledge of the subject and will allow better and more reasonable discussions of the pollutions of water supplies, and the reasonable standards to be maintained in protecting waters from such pollutions, and in applying corrective measures where the pollutions themselves cannot be suppressed.

In discussing Mr. Crandall's paper, presented to this association in September, 1895, I ventured the statement that ten million dollars was not an overestimate of the loss in Chicago in one year, due to the polluted condition of the public water supply. This was based on typhoid statistics alone. Since that time I have become convinced that typhoid fever, as Professor Sedgwick suggested at the time, and as Mr. Baker now confirms, is wholly inadequate to measure the extent of damage caused by a polluted water supply, and the figure then given for Chicago was probably far below the real damage which resulted to the citizens of that city from the condition of the public water supply; and the loss was so great that it would amply justify almost any measures which might be necessary for the correction of the difficulty.

In the case of Burlington the amount of sickness and death which can be attributed to the water supply is small in proportion, but still, when carefully followed out and estimated, and reduced as well as it can be to a financial basis, it may be, and very likely is, far more than enough to justify whatever expense may be necessary in changing or improving the supply, as for instance, by filtration, as Mr. Baker recommends.

The day is rapidly passing when cities can continue to exist and

prosper while killing their citizens by impure water. Already it makes a great difference with the prosperity of a city whether its water supply is healthful or not. It will not be many years before intelligent people will refuse to live in a city where they are subject to such dangers. The question is no longer whether or not it is worth while to furnish good water. It is getting to be whether a city shall continue to exist; for I believe the day is at hand when a city cannot exist in any adequate and satisfactory sense without a reasonably pure and wholesome public water supply.

MR. G. W. FULLER.* Mr. Baker's paper is an excellent one, suggesting broader and more reliable lines for water-works people to consider in dealing with the quality of public water supplies. The writer is heartily in sympathy with the studying of diarrheal diseases and their relation to drinking water. There is no doubt about polluted waters materially affecting general death-rates in this manner. Changes from polluted to relatively pure waters cause a marked reduction, not only in typhoid fever, but also in the general death-rate, principally through the influence upon the latter of deaths from diarrheal diseases. For some time there has been a growing feeling among sanitarians that this subject should receive more attention, and Mr. Baker is to be congratulated on his careful, painstaking data regarding the Burlington evidence.

The compilation of such statistics to show their influence upon the quality of public water supplies is not entirely new. In fact, it is understood that quite similar statistics were prepared under the direction of Mr. Rudolph Hering relative to the public water supply of Louisville, Ky., in 1892. Mr. Baker's paper shows, of course, in a striking manner the importance of having death certificates properly prepared, both as regards the diagnosis of the diseases producing death and their classification for accurate and ready reference in municipal records. In some ways the Burlington situation as to vital statistics is unusually free from complications as to other drinking waters than the public supply, although it is not free from questions of other general sources of infection, as mentioned by Mr. Baker in his paper.

Experiences of communities in discharging sewage into, and taking their water supply from, the same body of water are always

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interesting. Seldom has this proposition been faced with satisfactory results, although there are some instances where, under special conditions, this seems to have been true. The general question of the pollution of large bodies of water by sewage at points some distance removed from the point of sewage discharge is, of course, of growing importance to the sanitarians. To the writer it is particularly so as it bears indirectly upon the questions of foreshore pollution and the effect of sewage upon the shellfish industry. Views upon these matters are not so definite as they should be, and all carefully compiled data bearing upon the subject are of importance in getting views crystallized upon reliable and definite lines.

By those who have had to do with water supply matters for cities on the great lakes it will be noted at once that the Burlington intake, although three miles removed from the principal outfall sewer, is in water of a depth of only 30 feet, and that the intake is turned upward until it reaches within 14 feet of ordinary low water. In this respect the Burlington supply differs materially from those of a number of cities having relatively good water from the great lakes. Reference is made to the fact that the lake water near the Burlington intake is so shallow that sediment, some of it presumably of sewage origin, is stirred up during heavy winds, and further that the supply is not protected by stratification from pollution by intermingling with the upper water. As to the effect of wind disturbances, it may be said that experience shows that severe storms may disturb large bodies of water to a depth of some 35 feet below the mean level. Stratification is of great importance, for instance at Milwaukee, where the water is drawn from Lake Michigan at a depth of some 80 or 90 feet, from a point where the bottom water remains at about maximum density very near all the time. In this way, although sewage may, perhaps, at times be driven by currents to the vicinity of the intake, the upper water, of lighter specific gravity and, perhaps, of doubtful quality, does not reach the intake. The latter is polluted, if at all, only by those bacteria which by chance settle from the upper water to the intake. The influence of this is presumably no greater than that of the residual bacteria in the effluent of a well-managed filter plant.

Several years ago the writer had occasion to investigate this matter at places both on Lake Erie and Lake Ontario. In the former lake it is probable that stratification hardly takes place to a degree to give much assistance in securing a good source of water supply. But in Lake Ontario, in the vicinity of Oswego, it was found that at a depth of 80 feet the water remains stratified with the exception of short intervals in the spring and fall, when there was an overturning from top to bottom. While stratification existed, the water at the bottom, with a lower temperature and higher density, showed no measurable effect of pollution even when winds and currents drove some of the harbor water along the surface to the vicinity of the proposed intake. Should such wind and current conditions prevail during the comparatively short period of overturning in the spring and fall, when stratification is absent, such protection could not be counted upon. With water from such a source supplied without filtration, it becomes desirable, and in some cases necessary, to be prepared to draw water from storage during conditions favoring the passage of polluted water to the vicinity of the intake.

Another point of some interest in this connection was encountered in a study of the water supply of Buffalo and suburbs, viz.: That winds generally produce an undercurrent moving in the opposite direction to that from which the wind blows. In this way, pollution, either through surface or undercurrents, may be carried probably to a greater distance than is generally appreciated.

Pollution of water supplies does not have to occur every day in the year in order to produce serious trouble. While it is important to settle the question, as Mr. Baker suggests, of whether there is a leak in the intake of the Burlington supply in order to show the effect of an unfiltered water supply from the present intake upon the consumers, it is not unlikely that during a few days in the year the water from the intake itself, due to conditions of wind and weather, is much below normal quality.

In the opinion of the writer the tests by so-called presumption methods for the presence of fecal bacteria in water require great caution in interpreting results.

DR. GEORGE A. SOPER.* It is unusual to find a paper upon the

* Consulting Sanitary Engineer, New York City.

effects of impure water which has been so carefully prepared as the one under discussion. It is one of the most thorough and painstaking studies which have appeared, and the city of Burlington, no less than the members of this association, should feel indebted to Mr. Baker and those whose labors have contributed to this work.

The single point which I desire to refer to in discussing the paper has to do with the amount of sickness which can fairly be attributed to the water. Should we go beyond the statistics of typhoid fever in estimating the extent of the connection between a water supply and disease? and if so, how far? In other words, what forms of illness may be communicated by such a water supply as that of Burlington, and how can the fact of the connection of these diseases with the water supply be established?

In the present state of our knowledge, it seems desirable to restrict our view of the possible consequences of drinking sewage-polluted water to diseases of the bowels; not that the impurities in such water may not, in some cases, cause other disorders, but because the chances of their doing so are too remote for practical consideration.

Probably the most important and difficult disease to investigate in connection with a water supply is typhoid fever. Because of the many forms which typhoid may take and the existence of popular delusions concerning it, it is doubtful if the extent of this disease is ever known with accuracy.

In investigating the cause and extent of existing outbreaks of typhoid fever, it has been my custom for years to study not only the cases of sickness which were readily recognized to be typhoid, but also those forms of illness which, by any chance, might be typhoidal in nature. I have generally included in this list cases reported as paratyphoid, paracolon, enteric fever, fall fever, dysentery, enteritis, diarrhea, and malaria. Recently I have added pneumonia, bronchitis, and tuberculosis, for I have not infrequently found genuine typhoid treated by physicians as these diseases. All such cases have been regarded in my investigations as of a doubtful or unsettled character until a special study of them could be made to ascertain with positiveness their real nature. Even with these precautions, it has been impossible to

detect every case of typhoid. Exceedingly mild cases are often not reported by physicians at all. Sometimes erroneous or fanciful names are deliberately given to typhoid with the object of hiding the nature of the disease.

The kind of study made necessary by such an investigation requires the services of a number of trained assistants and the use of a laboratory for examining blood and other pathological and sanitary work. But these adjuncts are what should be available in investigations of epidemic diseases wherever an attempt is made to carry them on thoroughly, and I have generally found it practical to obtain all the facilities needed. This was so at Ithaca, N. Y.; Watertown, N. Y.; Williamstown, Mass.; Lawrence, N. Y.; and elsewhere. My chief difficulty has been in obtaining competent assistants.

In inquiring into the past records of disease no such satisfactory measures can be used to determine the exact number of typhoid cases. It may always be assumed that the number has been larger than that reported, but the ratio between the real number and the number indicated in the health records is never ascertainable. Cities which have the most typhoid are apt to be the most indifferent to it; their records, also, are likely to be the most inaccurate.

Mr. Baker has presented in his paper records of diarrheal diseases beside typhoid; not, apparently, with the idea that many of these cases were perhaps genuine typhoid, but because it seemed fair to suppose that many of them had been produced by the water supply. This appears to me to be a natural conclusion. Conditions which result in the contamination of a water supply with the germs of typhoid are also likely to lead to its pollution with the germs of other diseases. It is probable that a water supply is sometimes infested with the germs of several intestinal diseases at the same time. This is, I think, sufficiently indicated by the fact that in any large typhoid epidemic, various other diarrheal diseases, which are not typhoid, are apt to be met with. The diseases produced depend upon the nature of the microorganisms contained in the filth which defiles the water. At Ithaca there were several annual visitations of diarrheal diseases before the extensive epidemic of 1903; during the progress of that

epidemic several diarrheal diseases other than typhoid occurred and were believed to have been caused by the water. The typhoid epidemic at Watertown, N. Y., in 1904, was preceded by an epidemic wave of diarrhea.

Yet I am inclined to believe that records of other diarrheal diseases beside typhoid should be used with caution. So many other conditions may account for these disorders that it seems unsafe to ascribe an undue excess of them to water unless the other factors which enter into their etiology have been eliminated after careful study. The industrial conditions which prevail in a city may have a marked effect upon the infant mortality, and infant mortality usually represents the major part of diarrheal diseases not typhoid. The nationality of the population and their degree of intelligence and education are important factors in the matter. Above all, the condition of the milk supplies, the spring water supplies, the severity of the weather, the clean or dirty condition of the city and the housing of the laboring classes are conditions which should be taken very carefully into account before drawing any conclusions as to the cause of an undue prevalence of diarrheal diseases. In investigating these questions, whether they relate to present or past conditions, the coöperation and assistance of local physicians can sometimes be used to advantage, for although they are often poorly informed in matters of hygiene and the more scientific aspects of the causes of disease, their opportunities for observation are unrivaled and they are sometimes well informed.

Among the manifest difficulties to be met with in investigating the past records of diarrheal diseases in a city are those which rise from the fact that the conditions which should be studied in order to properly interpret the statistics are matters of history, often imperfectly recorded, and no longer subject to minute investigation. The making and interpretation of vital statistics is subject to more error than almost any other form of statistical work.

It is well known to the members of this association that what appears to be one of the most remarkable results of introducing a supply of pure water into a city whose water supply has previously been impure is a seeming reduction in the occurrence of

diseases whose causes have no conceivable connection with drinking water. The statistics sometimes make it appear that the number of cases of practically all forms of disease has been reduced. If we were to credit the records and believe this theory, it would be necessary also to believe that its converse was true,—that the amount of sickness and death from all forms of disease was increased by impure water. If this opinion was held, it would be necessary in such a study as this one of Mr. Baker's to take account of every case and death known to the health authorities. I am far from saying that this would be an undesirable proceeding, but I do not think it would be warranted on the ground that the theory just alluded to was correct.

In fact I doubt whether it is true that the introduction of a pure water supply reduces the general death-rate as much as appears. It seems possible that often as much of a change takes place in the methods of keeping the records and interpreting them as in the health of the people, excepting so far as enteric diseases are concerned, and even here the beneficial results may be unintentionally exaggerated. In the sanitary awakening which a city experiences when a pure water supply is introduced, the condition of the public health and the work of the health office assume an importance and receive an amount of attention which they have never before known. From a position of comparative obscurity and neglect, the business of the board of health emerges into one of great prominence and responsibility. Everybody looks to the board to mark with official precision the extent of the improvement. Those persons who have to do with the records naturally share in this interest and desire that the city shall have as clean a bill of health as practicable. The report of each case of sickness and death is scrutinized with extreme care. Physicians are on their mettle. As few cases and as few deaths are charged against the city as is legally possible. Not seldom the sickness and death of persons from outside of the city who are taken ill within the limits, or are brought there for treatment, are recorded, after the installation of the new water supply, as having occurred in the places where the deceased claimed residence. In these ways the vital statistics are sometimes influenced without any intention on the part of any one to deceive.

When it is appreciated that cases of the commonest diseases due to impure water supplies often differ so markedly in appearance that physicians make mistakes in diagnosing them, that boards of health are often lax in keeping the records, that many other factors than the water supply contribute to the spread of what are known as water-borne diseases, and that the time and skill necessary to investigate the facts are seldom available, the value of such a long and careful study as Mr. Baker has made becomes evident.

Condensing my views on the subject to a simple and brief form, I should say that in studying the possible relation between a water supply and the health of a city, it is desirable to take account not only of the occurrence of typhoid, but of practically every other form of disease which occurs in the vicinity. The official records should be used more as clews to the truth than as evidence which needs no verification. Wherever possible, the investigation should call to its aid modern methods of pathological study. The value of the investigation will usually depend not only upon the official records or other information which may have been already collected, but also upon the skill and thoroughness with which the information thus offered is studied, checked, amplified, and interpreted.

The investigation of the Burlington situation has been fortunate in some respects. The statistical records seem to have been remarkably full and reliable, and the situation has been studied with a degree of thoroughness, competency and impartiality which, up to this time, has been very unusual. In the future, sanitary investigations of a far more exacting character than we have been accustomed to will have to be made. It is a vast mistake to suppose that only those sanitary matters need investigation and correction which are conspicuously dangerous. The investigation and correction of the more subtle and obscure causes of disease are at least of equal importance.

DR. JOHN S. FULTON.* The statistical exhibit which Mr. Baker has made of certain causes of death in Burlington between 1879 and 1905, and the arguments which he makes for a more liberal use of mortality data in determining the sanitary quality

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of the public water supply, seem to me most interesting. It is not surprising that Mr. Baker should have overlooked an important source of fallacy which affects all vital statistics, since the source to which I refer lies wholly in the domain of medicine, and is but little known outside the medical profession. It is difficult to bring medical men to realize the unreliability of the data which they themselves supply. All mortality statistics are based on the death certificate, and non-medical statisticians generally regard the death certificate as of fixed interpretation. As a matter of fact, however, medical men seldom write a death certificate with any appreciation of its utility as a contribution to vital statistics.

Its use as a basis for a burial permit is the only significance of a death certificate to a physician who is writing such a certificate. When these small documents in large numbers come up for statistical treatment their proper statistical reference is sometimes very difficult to determine. Not one physician in a thousand knows or cares anything about the nomenclature employed for statistical purposes. These nomenclatures themselves have their faults, and the very best that medical statisticians can do in these days is to move toward some sort of uniformity.

Too often the mortality data of American cities are made over into statistical tables by inexpert persons who are quite incompetent to translate the phraseology of a certifying physician into the rigid nomenclature of a statistical classification. In some items the terms of the classifications are vague, and very often the phraseology of a physician is vague. There is hardly any class of causes of death which admit so great a variety of vague terms as those diseases which are known as diarrheal diseases.

I suppose the term *typhoid fever* represents to the average layman a very definite cause of death. This term in pathology assuredly has a definite significance, but in clinical medicine the term "typhoid fever" in American practice does not occur in more than 60 per cent. of the certificates recording deaths which are really due to typhoid fever. At the present moment 40 per cent. of the cases of typhoid fever either wholly escape the diagnosis of attending physicians, or else, when death occurs, are recorded under some more or less vague name. If we trace typhoid fever back in the statistics we will find that the percentage

of error increases the farther back we go, and for twenty-five years backward we find some twenty-five or thirty more or less confusing phrases employed by physicians to indicate deaths which, in all probability, were due to typhoid fever. Medical statisticians have but gradually come to understand this. A note in the first of Mr. Baker's tables says that the Burlington statistician has wisely added to the typhoid deaths the deaths reported as "bilious," "continued," "enteric," "slow," "typho-malarial" fevers. A similar note under Table No. 4 makes a similar exhibit and shows besides that the use of these unmeaning terms was far more prevalent formerly than now, although the absurd term "bilious fever" appears in Burlington's statistics as late as 1901. The terms *enteritis* and *gastro-enteritis* signify, for the most part, the medical man's confusion in the matter of diagnosis, though the statistician may have included in the *enteritis* column a certain number of deaths whose certificates did not bear the word *enteritis*. More than half of the deaths recorded under these two heads ought to be added to the typhoid fever column. If the deaths under five years of age, which have been ascribed to these two causes, could be taken away, 80 per cent. of the remainder could be added to the typhoid fever column without in the least overstating the truth about typhoid fever in Burlington between the years 1879 and 1905. One notes that the enteritis column includes here and there a death from *intestinal colic*. Intestinal colic probably means appendicitis, and the error of diagnosis in appendicitis also increases the further back one goes in the history of mortality. The *colitis* column includes certificates ascribing death to entero-colitis. A majority of these cases (enteritis, gastro-enteritis, entero-colitis, colitis), nearly all of those which were characterized by diarrhea, a duration of two weeks or longer, and ages above five years, should be added to the typhoid fever column. The remainder should be added to the dysentery column, and the small group of cases under the head of ulceration of the bowels should also be added to the dysentery column. The cholera morbus cases, which are few in number, have probably no relation whatever either to typhoid fever or to the water supply. Deaths classified under the heading cholera infantum probably include very few, if any, cases of typhoid fever, and these bear, in all

probability, no considerable relation to the public water supply of Burlington. It will be seen, therefore, that a medical man's views bring him into substantial agreement with Mr. Baker's contention that, besides typhoid fever, several other columns of current mortality ought to be consulted in determining the sanitary quality of a public water supply. It would not be necessary, however, to consult half a dozen different items of mortality, if medical men were firmly convinced of the truth that typhoid fever is the commonest continued fever met with in the United States; for if this knowledge were faithfully reflected in the death certificates, such vague statistical terms as enteritis, gastro-enteritis, enterocolitis, would become emaciated almost to extinction. It will thus be seen that I can agree heartily with the main contention of Mr. Baker's paper and still believe that typhoid fever (frank typhoid fever plus disguised typhoid fever) will still remain the best, and almost sufficient, index of the sanitary quality of a public water supply.

MR. BAKER (*by letter*). I first wish to express my pleasure with the amount and character of the oral and written discussion, and with the fact that the paper has been received and considered as an attempt to present, in a rather tentative manner, some of the broader relations between water supply and disease than can be brought out by typhoid statistics alone. I also wish to say at the outset that some of the vital statistics presented in the paper were included for the purpose of throwing light on the deficiencies in the typhoid statistics rather than because they bear any well-defined relation to the character of the Burlington water supply. In fact, it seems more and more evident to the author that other sanitary conditions at Burlington are in almost as much need of investigation and improvement as is the water supply.

The author is particularly grateful to Messrs. Stone and Moat for their additional data on conditions at Burlington, Winooski, and Fort Ethan Allen. Had these data been in his possession before the paper was written he would have given more weight to the effect on the Burlington water supply of the pollution brought down by the Winooski River. Nevertheless, until further evidence is produced it can hardly be disputed that even

if all pollution were removed from the Winooski River, the Burlington sewer alone would render the water supply so dangerous at times as to make its use without thorough purification unwise. This, it should be said, Messrs. Stone and Moat would doubtless be the first to admit. The author agrees with Dr. Stone that the study of leakage in the water intake is an engineering rather than an analytical problem; or perhaps demands the aid of both methods. Seemingly, it would be a simple matter to test the intake for leakage, and no further time should be lost before doing so. The need of better records of vital statistics at Winooski and more thorough investigations of all reported cases of communicable disease at both Winooski and Burlington is evident. Every reported case of typhoid fever in the two municipalities and at the Fort should be looked into most carefully for the purpose of showing both its origin and its possible or probable effect upon the Burlington water supply. If this were done, and if careful analytical tests of river, lake, and city water were made at frequent intervals, and if at the same time both cases and deaths of diarrheal diseases were systematically studied, much additional light might be thrown on water supply and disease at Burlington and elsewhere. Much of this work properly belongs to the several local authorities, but in carrying it out there might well be coöperation between them and the State Laboratory of Hygiene.

Mr. Leighton is peculiarly qualified to discuss the paper, on account of the studies of the pollution of Lake Champlain already mentioned. His belief that within the past few years typhoid fever has been fully reported at Burlington is in part supported by all the evidence before us, but only in part. That there has been improvement there can be no doubt, but the continued high diarrheal mortality indicates faulty nomenclature, to say the least. This indication is supported by the excess of positive Widal reaction tests, as given by Dr. Stone, over reported typhoid cases, unless the Widal reports include duplicate tests. In 1905, in particular, the positive Widal tests numbered 77, against 32 reported cases of typhoid fever. It is gratifying to note, however, that the Burlington physicians seem to be trying to learn the truth, for in 1905 there were 113 negative as well as 77 positive Widal tests. It may be noted that Mr. Leighton, contrary

TABLE No. 12.—Table Designed to Show Effect of Ice over Lake Champlain on Typhoid Mortality at Burlington, Vt.

	Broad Lake.		Days	Typhoid Deaths.	
	Closed.	Opened.	Closed.	Jan.-Mar.	Year.
1890	February 10, 21 March 7	February 11, 28 March 12	13	2	4
1891	January 27 February 14 March 8	January 31 February 27 April 2	42	3	4
1892	February 14	April 3	49	2	7
1893	January 16	April 12	86	7	10
1894	February 6, 12	February 10 March 15	35	1	2
1895	February 7	April 19	71	0	1
1896	February 17	April 17	60	1	4
1897	January 31	April 10	69	0	2
1898	January 30	March 16	45	3	5
1899	February 1	April 20	78	1	2
1900	February 28	April 19	50	4	7
1901	February 1	April 11	69	3	5
1902	January 30	March 28	57	0	2
1903	January 24 February 19	January 30 March 12	27	0	3
1904	January 19	April 13	85	1	7
1905	January 23	April 13	80	2	3
	Total Deaths	(average closure)	57	30	68

The bay at Burlington and also the Winooski River would be covered with ice when the "broad lake," which is here some ten miles wide, is not frozen from shore to shore. Earlier statements regarding lake closure are not available. The observations given were recorded by Mr. Charles Allen, of Burlington, Vt.

to Dr. Stone, suggests bacterial tests to ascertain the tightness of the intake. Mr. Leighton's remark to the effect that the monthly distribution of typhoid (Table No. 4) shows that the disease is at its worst when the lake is covered with ice (or really in the months when such a covering would be expected) leads me to include a table (Table No. 12) compiled from the city reports of Burlington, showing for the past sixteen years the dates on which the "broad lake" closed and opened opposite Burlington, the days closed each winter and the number of typhoid deaths for the January–March quarters of the corresponding years, and the total numbers of typhoid deaths for the several years.

While the figures in detail do not show as much connection as might be expected between a disproportionate amount of typhoid in the first quarter of the year and a long period of ice closure of the lake, yet it may be noted that, in 1893, the worst typhoid year indicated by the table, 7 of the 10 typhoid deaths occurred

in the first quarter, and in that year the lake closed earlier and remained closed longer than any other year of the sixteen. The following winter was an open one, and in August (1894) the water intake extension was put in use. Only two typhoid deaths were recorded, one of which was in the first quarter. In 1895, the lake was closed seventy-one days, but there was only one typhoid death, and that in the later part of the year. The effect of the new intake was shown in this and a number of subsequent years, but beginning with 1900, typhoid again rose. With the exception of 1900 and 1904, typhoid has been highest when the lake was closed longest, and in three of the six years more than half of the typhoid deaths have been in the first quarter of the year. It should be noted that the bay and river, the region of sewage influence, are closed earlier and longer than the broad lake, and that the table inserted in this discussion shows that for the whole sixteen years 30 of the 68 typhoid deaths recorded were in the first quarter of the year when they would be least expected, pointing undoubtedly to the protective effect of ice covering on the typhoid germs in the lake water. With the recurrence of typhoid from 1900 on, only 10 of the 27 recorded typhoid deaths were in the January-March quarter, indicating that the typhoid infection, from whatever source, is becoming more generally distributed throughout the year.

Mr. Weston suggests that hospitals in general have little effect, that need be considered, on the vital statistics of cities. This may be true for large cities, for, as Mr. Weston says, the out-of-town patents who die in such hospitals may be balanced by the people of those cities who die elsewhere. But in a city like Burlington, with no hospital in near-by places, the out-of-town patients are less likely to be balanced in such a way. Dr. Stone also states as his belief that the hospital at Burlington has little effect on the number of typhoid deaths, since the taking of typhoid cases is avoided there. Probably the Burlington hospital does have but little effect on typhoid in Burlington, but doubtless it accounts in part for the high general mortality in that city. The two childrens' homes, taking children from without the city, add to the under-five population, and therefore contribute to the unduly high infant mortality.

It is to be regretted that the Louisville figures mentioned by Mr. Fuller could not be included in the discussion. The author is informed that Mr. George C. Whipple has also collected some diarrheal statistics in connection with water supply studies at Cleveland, Ohio. Mr. Fuller's remarks on the need of caution in interpreting results obtained with presumptive methods for determining fecal bacteria deserve attention in connection with the large number of colon bacilli reported as found at Burlington.

Dr. Soper's remarks, like those by Mr. Hazen and others, endorse the author's general idea of broadening the scope of the vital statistics commonly used in studying the effects of water supplies on the public health. Dr. Soper would go even further afield, taking in other than diarrheal diseases, not because these are caused by bad water, but because, for one reason or another, they cover up many typhoid cases and deaths. The author agrees with Dr. Soper that the diarrheal statistics should be used with caution and that a variety of other factors than the water supply should be considered in studying diarrheal mortality. It is particularly desirable that this should be done at Burlington, where, as the author pointed out in his report to that city in 1905, the sanitary condition of the milk supply has received very little attention as yet, and where housing conditions and infant feeding, among a considerable part of the population, are probably bad.

The association and the author have reason to be thankful for the discussion contributed by so eminent a vital statistician as Dr. Fulton. It is only fair to the health officials of Burlington for the author to take upon himself the full responsibility, as he thought he made plain in the paper, for searching out in the twenty-six annual reports and grouping together by years and classes all the statistics included in the tables, and for making the reclassifications indicated by footnotes. In no one of the Burlington reports is there a comparative study of any of these mortality figures by years, nor did any of the health officers, so far as the reports show, ever reclassify as typhoid fever a death reported by a physician as "bilious" fever, "continued" fever, etc. In the same year the mortality reports include deaths from typhoid fever and enteric fever as though the two diseases were not identical. The later reports bear circumstantial evidence,

but no direct proof, that some reclassifications have been made by the health officer. Probably, however, the disappearance of "bilious" fever and the like from the mortality tables is largely due to improvement in the nomenclature used by the practicing physicians.

Finally, the author expresses a hope that other attempts will be made to broaden the studies of the relations between typhoid and the public health; that health officers and practicing physicians will devote themselves far more earnestly and intelligently than heretofore to the perfection of vital statistics, both in completeness and in classification; and that the city of Burlington will soon find some permanent means of improving the character of its water supply and, what is, perhaps, even more important, of introducing other sanitary reforms, all of which combined will result in the reduction of its typhoid, diarrheal, infantile, and total mortality to a figure appropriate for a city of its unsurpassed natural conditions.

PROCEEDINGS.

March Meeting.

Hotel Brunswick,
Boston, March 14, 1906.

The President, Prof. W. T. Sedgwick, in the chair.

The following members and guests were in attendance:

Members.

M. N. Baker, C. H. Baldwin, L. M. Bancroft, W. T. Barnes, G. W. Batchelder, J. E. Beals, E. M. Blake, George Bowers, E. C. Brooks, G. A. P. Bucknam, J. C. Chase, R. C. P. Coggeshall, M. F. Collins, E. R. Dyer, H. P. Eddy, E. D. Eldredge, I. T. Farnham, J. N. Ferguson, Desmond FitzGerald, F. F. Forbes, D. W. French, T. C. Gleason, A. S. Glover, F. W. Gow, J. O. Hall, J. C. Hammond, Jr., L. M. Hastings, V. C. Hastings, H. G. Holden, J. L. Howard, E. W. Kent, Willard Kent, L. P. Kinnicutt, H. V. Macksey, D. E. Makepeace, A. D. Marble, A. E. Martin, W. E. Maybury, John Mayo, A. S. Merrill, F. E. Merrill, H. A. Miller, C. A. Mixer, Wm. Naylor, G. H. Palmer, W. W. Robertson, C. M. Saville, E. M. Shedd, C. W. Sherman, Sidney Smith, G. H. Snell, G. A. Stacy, J. T. Stevens, R. J. Thomas, H. L. Thomas, W. H. Thomas, W. H. Vaughn, R. S. Weston, J. C. Whitney, O. J. Whitney, I. S. Wood, C.-E. A. Winslow, G. E. Winslow, E. T. Wiswall. — 64.

Honorary Members.

W. T. Sedgwick, F. W. Shepperd. — 2.

Associates.

Builders Iron Foundry, by F. N. Connet; Chapman Valve Mfg. Co., by Edw. F. Hughes; The Fairbanks Co., by F. A. Leavitt; Hersey Mfg. Co., by Albert S. Glover, Jas. A. Tilden, H. D. Winton, H. V. Macksey; International Steam Pump Co., by Samuel Harrison; Macleod & Co., by W. F. Stoddard; Ludlow Valve Mfg. Co., by H. F. Gould; H. Mueller Mfg. Co., by G. A. Caldwell; National Lead Co., by G. L. Whittemore and H. McConaghy; National Meter Co., by C. H. Baldwin and J. G. Lufkin; Neptune Meter Co., by H. H. Kinsey and F. W. Hawks; Rensselaer Mfg. Co., by F. S. Bates and C. L. Brown; A. P. Smith Mfg. Co., by F. N. Whitcomb; Thomson Meter Co., by Edward M. Shedd; Union Water Meter Co., by W. F. Hogan; United States Cast Iron Pipe & Foundry Co., by F. W. Nevins; R. D. Wood & Co., by Wm. F. Woodburn. — 24.

GUESTS.

Hon. Thomas Thompson, Mayor, New Bedford, Mass.; T. H. Dearing, M.D., Water Commissioner, Henry A. Monk, Clerk, and John Kelly, Water Commissioner, Braintree, Mass.; Clarence Goldsmith, Supt., North Andover, Mass.; C. W. Gilbert, Woburn, Mass.; R. R. Thomas, Quincy, Mass.; F. L. Clapp, Stoughton, Mass.; A. H. French, Brookline, Mass.; G. A. Sampson, Boston, Mass.; C. Story, H. M. McRae, G. H. Bryant, G. H. Hanley, G. E. Washburn; C. H. Rollins, Water Commissioner, Watertown, Mass. — 16.
[Names counted twice. — 4.]

After the dinner had been served, President Sedgwick called the company to order, and said:

"Death has invaded our membership since the last meeting and taken from us one of our vice-presidents, Mr. Frank A. Andrews, of Nashua, N. H.; and another member, Mr. T. W. Mann, of Holyoke, has also died. These events remind us that the association is always losing at one end and needs always to be gaining at the other; in other words, we must ever be on the lookout for new members to take the places of those who pass away. This association can do its best work only if it has a large and vigorous membership, provided, of course, that that membership is of the right quality. In the Executive Committee meeting to-day we have been discussing the advisability of adding steadily new and fit material to our membership. Let each one of us see to it that no man who ought to be a member goes on long without being proposed for membership The Executive Committee will be glad at any time to receive applications.

"The next meeting of the association will be the annual field-day meeting. For this plans are not yet fully matured, and the Executive Committee would be pleased if any members who have bright ideas as to proper 'stunts' to carry out on field day would communicate those ideas to the committee. In other words, the Executive Committee will welcome hints from all sources, — although they will not promise to adopt any of them.

"The first business in order is the election of new members, and I will ask the Secretary to read the names of candidates who have been passed and approved to-day by the Executive Committee."

The Secretary read the names of the following applicants for membership:

Ransom Rowe, Lynnfield, Mass., Water-Works Contractor; James A. Tilden, Hyde Park, Mass., Mechanical Engineer; George G. Honness, Katonah, West Chester County, N. Y., with the New York City Aqueduct Commission; Dabney H. Maury, Peoria, Ill., Consulting Engineer; Nicholas P. Simin, Moscow, Russia, Chief Engineer, Moscow Water Works; Francis F. Longley, Washington, D. C., engaged in water supply, water purification, and other engineering work.

On motion of Mr. Bancroft, the Secretary was directed to cast the ballot of the association in favor of the applicants, and they were declared elected.

THE PRESIDENT. Massachusetts is a state of cities, and among the cities that adorn the state and, as we believe, adorn New England, there are few more thriving or more prosperous than New Bedford. We are fortunate in having as one of our guests to-day the chief magistrate of that city, Mayor Thompson, who has kindly consented to say a word to us as members of the New England Water Works Association. I have great pleasure in presenting Mayor Thompson of New Bedford.

Mayor Thompson was received with hearty applause, and in response said:

Mr. Chairman and Gentlemen, — It is a pleasure for me to be here before such an intellectual body of men, especially as all are designated as being on the water wagon. [Laughter.]

New Bedford is a thriving city, and no doubt every one of you has read of some of the conditions which are surrounding the municipality of New Bedford. There are peculiarities that surround every municipality, and New Bedford is no exception, although we pride ourselves on being the first city in this great country in what we call the manufacture of fine goods. We have 42 cotton factories in New Bedford, with a capital stock of about $15 829 000. The amount of dividends paid last year was $829 500, or about 5.94 per cent. upon the money invested.

There is one thing that we had to do, and that was to increase the water rates to the manufacturing interests in New Bedford. It shouldn't have been done, but as they desired to have the water department upon a paying basis they placed from two and one-half cents a thousand gallons up to fifteen, making an addi-

tional expense to the cotton factories and the various other manufactories in New Bedford of about $65 000.

We are trying to put meters in to the best of our ability, but some man up here in our legislature, who is more conversant with crazy quilts than he is with meter systems, is trying to compel all municipalities in Massachusetts to meter every service and and to attach a penalty if you don't do it before a certain date.

Now, I think we citizens of Massachusetts have, to a degree, lost faith in our representatives and our senate, simply because we don't go around and look after these freak bills that are being presented to the legislature by interested people.

There is no doubt of it, there has been a peculiar situation in New Bedford. We have a license commission. The license commissioners are appointed by the mayor and controlled by the mayor. The license commissioners do not grant the licenses; they vote for them, that is all, but the mayor selects those who shall have the licenses and the commissioners simply concur. And why? Simply because when it comes up to a question of an election they want to have those fellows, because you know there is more profit in whiskey than there is in molasses, because when business is poor they can put the hose into the barrel and forget to take it out, and so when they can't get a percentage over the counter in any other way they can make it on the water, for we only charge $2.50 for a faucet. [Laughter.] So you see that, he having the control of that department, it is very easy for him to say when it comes election time to one of these men, "I should like to have $500 from you for the campaign fund." He says, "I can't afford to pay it." Put the pencil through his name; he can't have a license. But he don't want to go back and work in a sewer; he don't want to use a pick.

They tell a story down in New Bedford about a fellow who was down on the wharf looking at one of the old whalers, and his attention was attracted by a big anchor which was lying there. He stayed round so long that finally somebody asked him what he was waiting for. He replied, "I am waiting to see the man who uses that big pick." [Laughter.] Now, these fellows don't want to go out and work with a pick or a shovel; they know there is more profit in the liquor business. They know they can make

four or five thousand dollars a year, and for the chance to make it they are willing to pay that $500. The legislature of Massachusetts has placed that upon us by saying there shall be one license for every 1 000 people in a municipality, so New Bedford has about 74 licenses. And, of course, for years past we have been subjected to what you may call the pseudo-apothecary shop. It is patent medicines and Peruna alongside of nursing bottles and liver pads. Down cellar they make the goods and in the back shop they deliver up. [Laughter.]

And the municipality has been retrogressive along these lines and spending its money extravagantly, actually throwing it away; in the month of January, under the new overseers of the poor that I placed there, we saved $50 a day even in our poorhouse, and on the outside we saved $60 a day, making $110 a day, and without any real detriment to the municipality of New Bedford. But because of the former extravagance we were forced to saddle upon the manufacturers of the city of New Bedford $65 000, and then our water department receives the blame, because of the extravagance and the incompetency of the men who have handled the administration.

So I say to you men who are trying to give the people what will be beneficial to them, and to bring to the man bloom upon his cheek and not waste and take from the man or curb his physical or destroy his mental powers, that these men, who hold the reins of government through the power of liquor have simply subjected the water boards of Massachusetts to that condition of things, and it will happen in every municipality of Massachusetts, I care not which it is, unless we can arrest that condition that monopolizes man and makes him bow subservient to the selfish ambition of any man or any coterie of men. And if you men are alive to the situation of a progressive municipality you can take this thing in hand; and that is the paramount question to all other questions, because the water departments of this great state are proving to us the possibilities of municipal ownership in the near future, so that the car tracks and lighting and so forth shall come into the hands of the people in order that the people may have the revenues from what they consume and pay for. And if you men will only just clasp hands in one great chain

from the Berkshire Hills to old Cape Cod, you can give Massachusetts better legislation by sending better men to the legislature, who will enact laws that shall be beneficial to the great body of the citizens of Massachusetts, so that posterity can walk in a narrow path and climb the mountains in the future because we have fought and have educated them to fight for the solution of the great and complex questions that confront us in this great and growing country of ours. Gentlemen, I thank you. [Applause.]

THE PRESIDENT. Mayor Thompson has touched on many points of interest to water-works men, certainly on one which we can all subscribe to, and that is that in our municipalities not infrequently water boards have suffered because of extravagance or ill-advised efforts in other municipal directions. What is greatly needed is some wise supervision of all municipal affairs, so that the schools and the streets, the water department and all other departments shall have their just and proper share of funds. We are grateful to you, Mr. Mayor, for bringing up these points.

The principal paper of the day, gentlemen, will be by one of our own members, the distinguished associate editor of an important engineering paper, the *Engineering News*, and a gentleman whose activities range over a wide field. Mr. Baker is not only an expert on water and water supply, but he is the president of one of the best boards of health in the United States, the board of health of Montclair, N. J. I know of my own knowledge that this board has been more progressive, more scientific, more courageous, and more successful than almost any other local board of health of any place of equal size in the United States; and I believe that to be so largely because it has had upon it good physicians, good citizens, and especially a good engineer in the person of Mr. Baker.

This association has always been interested in sanitary questions, particularly as affecting water supplies. Many of you who have been connected with it as long as I have, or longer, have seen great changes in our attitude and in the attitude of the public toward water supplies, and some of you have heard in the past about the conditions at Burlington, Vt. Mr. Baker is thoroughly familiar with the conditions there, and especially with the modern conditions, and I esteem it a great privilege that we are to hear

from him this afternoon upon the water supply and certain sanitary matters connected with the water supply of Burlington.

It is a matter of regret that no representative, as far as I know, is present to-day from that city. We have members there, but Burlington is a long way off. We have had submitted, however, typewritten comments upon Mr. Baker's paper by some of the municipal authorities of Burlington, and also by some members of the association, especially Mr. Hazen of New York and Mr. Leighton of Washington. I will ask Mr. Baker to present his paper now, but we will postpone our discussion of it for a short time while we listen to a description of the pitometer, which has been set up here in the middle of the room, by Mr. Blake, and then we will have a discussion of Mr. Baker's paper and, if time permits, of Mr. Blake's. I have great pleasure in presenting Mr. Baker. [Applause.]

MR. M. N. BAKER. I wish to thank the President for the kind word which he has spoken of the Montclair Board of Health, because I am deeply interested in having the work of boards of health throughout the country entered upon with more vigor, and I therefore welcome every opportunity which calls attention to the efforts which we have made, in the hope that similar efforts may be made in other communities; for, I regret to say, to a large extent throughout the whole country the work of local boards of health is, considering the vital interests involved, in a very shameful condition indeed.

Mr. Baker then proceeded with the presentation of his paper, which was entitled "Water Supply, Typhoid Fever, and Diarrheal Diseases in Burlington, Vt., 1879 to 1905, Inclusive."

EDMUND M. BLAKE, civil engineer, of Boston, explained "The Pitometer and Its Uses"; after which there was a discussion of Mr. Baker's paper. First, a communication from Dr. B. H. Stone, director of the State Laboratory of Hygiene at Burlington, Vt., was read by Mr. Coggeshall. Mr. Robert S. Weston, Mr. C.-E. A. Winslow and Prof. Leonard P. Kinnicutt participated in the oral discussion which followed, and papers by Mr. Allen Hazen and Mr. M. O. Leighton were presented.

On motion of Mr. Bowers the meeting adjourned.

EXECUTIVE COMMITTEE.

TREMONT TEMPLE, March 14, 1906.

Present: President William T. Sedgwick, R. J. Thomas, F. W. Gow, F. E. Merrill, L. M. Bancroft, Charles W. Sherman, John C. Chase, Willard Kent.

Six applications for membership were received and approved, *viz.*, Ransom Rowe, George G. Honness, Dabney H. Maury, James A. Tilden, Nicholas P. Simin, and Francis Fielding Longley.

On motion of Mr. Sherman, seconded by Mr. Thomas, the following ruling was unanimously adopted: "That applications for admission as members may be received from persons otherwise eligible, engaged in a technical capacity with firms dealing in, or manufacturing, water-works supplies, provided the said firms are already Associates."

Voted: That the President, Mr. Stacy, and Mr. Merrill, be a committee on the June Field Day with full powers, including that of adding additional members.

Voted: That the above committee be also a committee on the Annual Convention.

Voted: That, as an experiment, the tabulation of water-works statistics be omitted from the JOURNAL for the present year, but published next year and thereafter biennially.

Adjourned.

Attest: WILLARD KENT, *Secretary.*

OBITUARY.

THOMAS W. MANN, civil engineer, of Holyoke, Mass., died in that city on February 28, 1906.

Mr. Mann was born in Ireland about sixty years ago and came to this country when ten years of age, with his parents, who settled in Holyoke. After graduating from the Holyoke High School he received an appointment to West Point, but failed to pass the physical examination. He then took up civil engineering, and for some years he was employed by the Holyoke Water Power Company; later he opened an office for himself, which he maintained for some twenty-five years. He was town engineer of Holyoke before it became a city, and was city engineer in 1884 and 1885.

He became a member of the New England Water Works Association on June 9, 1892.

FRANK ALBERT ANDREWS, assistant superintendent of the Pennichuck Water Works, Nashua, N. H., and one of the vice-presidents of the New England Water Works Association, died on March 1, 1906.

Mr. Andrews was born in Nashua, August 3, 1865. He had been with the water company for twenty years, and had been assistant superintendent for several years.

In addition, he was a member of the insurance firm of Andrews, Son & Co., and was an officer of several corporations. A local paper says of him:

" Mr. Andrews was one of the sunniest of the active young men of the city. He was upright and in the open in all his business transactions, and in the social circles of those of his own age no man was more highly regarded as being unselfish and determined on doing all he could discover to do to add to the happiness of those with whom he was associated."

He was elected a member of the association on December 14, 1887.

JOHN JAMES ROBERTSON CROES, one of the most widely known civil and hydraulic engineers of this country, died March 17, 1906. Mr. Croes was a past president of the American Society of Civil Engineers, and an honorary member of the New England Water Works Association.

Mr. Croes was born in Richmond, Va., November 25, 1834. His early boyhood was passed in Terre Haute, Ind., and he was educated in the College of St. James, Hagerstown, Md., graduating in 1853. He then took up the study of civil engineering in the offices of practising engineers. He was employed on the Brooklyn Water Works, the New York Water Works, and the Washington Aqueduct; and then, after a short service under James P. Kirkwood on investigations relating to St. Louis and Cincinnati water works, returned, in 1865, to New York to take charge of surveys for storage reservoirs in the Croton valley. He was connected with the Croton Works for a number of years, and later with the New York Department of Parks. During the last twenty-five years he had been connected as chief engineer or consulting engineer with many important engineering enterprises.

Mr. Croes became a member of this association June 17, 1887, and on September 14, 1904, was made an honorary member.

BOOK NOTICE.

HYDRAULIC MOTORS. By Irving P. Church, M.C.E., Professor of Applied Mechanics and Hydraulics, Cornell University. New York: John Wiley & Sons. 1905. ix + 280 pages. 6 × 9 inches. Price, $2.00.

This excellent book has been prepared as a text-book to be used by students already well-grounded in the principles of mechanics and hydraulics. It is particularly adapted for use after Professor Church's "Mechanics of Engineering," to which it may be considered supplementary. Mathematics are used freely. Like all of Professor Church's writings, the reasoning is clear and logical, and the explanations are excellent.

The titles of the chapters are: Chapter I, General Considerations and Principal Types of Motors; Chapter II, Gravity Motors; Chapter III, Preliminary Theorems fundamental to the Theory of Turbines and Centrifugal Pumps; Chapter IV, Impulse Wheels; Chapter V, Turbines and Reaction Wheels; Chapter VI, Testing and Regulation of Turbines; Chapter VII, Centrifugal and "Turbine" Pumps; Chapter VIII, Pipes, Weirs, and Open Channels; Chapter IX, Pressure-Engine, Accumulators, and Hydraulic Rams; Appendix, Diagrams and Tables.

The several types of wheels are illustrated both diagrammatically and by views of actual wheels. Among the views are a number of excellent half-tone plates of some of the very large recent wheels.